

# BANYAN. V. A SYSTEMATIC ALL-SKY SURVEY FOR NEW VERY LATE-TYPE LOW-MASS STARS AND BROWN DWARFS IN NEARBY YOUNG MOVING GROUPS

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## ABSTRACT

We present the BANYAN All-Sky Survey (*BASS*) catalog, consisting of 228 new late-type (M4–L6) candidate members of nearby young moving groups (YMGs) with an expected false-positive rate of  $\sim 13\%$ . This sample includes 79 new candidate young brown dwarfs and 22 planetary-mass objects. These candidates were identified through the first systematic all-sky survey for late-type low-mass stars and brown dwarfs in YMGs. We cross-matched the *2MASS* and *AllWISE* catalogs outside of the galactic plane to build a sample of 98 970 potential  $\geq M5$  dwarfs in the solar neighborhood and calculated their proper motions with typical precisions of 5–15 mas yr<sup>−1</sup>. We selected highly probable candidate members of several YMGs from this sample using the Bayesian Analysis for Nearby Young AssociationS II tool (*BANYAN II*). We used the most probable statistical distances inferred from *BANYAN II* to estimate the spectral type and mass of these candidate YMG members. We used this unique sample to show tentative signs of mass segregation in the AB Doradus moving group and the Tucana-Horologium and Columba associations. The *BASS* sample has already been successful in identifying several new young brown dwarfs in earlier publications, and will be of great interest in studying the initial mass function of YMGs and for the search of exoplanets by direct imaging; the input sample of potential close-by  $\geq M5$  dwarfs will be useful to study the kinematics of low-mass stars and brown dwarfs and search for new proper motion pairs.

*Subject headings:* brown dwarfs — methods: data analysis — proper motions — stars: kinematics and dynamics — stars: low-mass

## 1. INTRODUCTION

A few decades ago, several groups of stars sharing similar galactic space velocities have been identified in the solar neighborhood. These similar kinematics are a consequence of the young age (typically 10–200 Myr) of these groups (i.e. young moving groups; YMGs), which formed from a common origin. The closest and youngest YMGs include the TW Hydrae association (TWA; de La Reza et al. 1989, Zuckerman & Song 2004; 5 – 15 Myr; Weinberger et al. 2013),  $\beta$  Pictoris ( $\beta$ PMG; Zuckerman et al. 2001; 20 – 26 Myr; Mamajek & Bell 2014, Malo et al. 2014b, Binks & Jeffries 2014), Tucana-Horologium (THA; Torres et al. 2000, Zuckerman & Webb 2000; 20 – 40 Myr; Kraus et al. 2014), Carina (CAR; 20 – 40 Myr; Torres et al. 2008), Columba (COL; 20 – 40 Myr; Torres et al. 2008), Argus (ARG; 30 – 50 Myr; Makarov & Urban 2000) and AB Doradus (ABDMG; Zuckerman et al. 2004; 110 – 130 Myr; Luhman et al. 2005, Barenfeld et al. 2013). Identifying these YMGs was made possible with the advent of the *HIPPARCOS* survey (Perryman et al. 1997), which provided parallax measurements for  $\sim 120,000$  bright stars. Because of its limited sensitivity and the fact that it operated at visible wavelengths, this survey mainly studied stars with spectral types earlier than  $\sim K0$ . Identifying the missing later-type, low-mass members of YMGs is of great interest for multiple reasons: it would provide constraints on the low-mass end of their initial mass function (IMF) and accessible benchmarks for cool, low-pressure atmospheres, similar to those of directly imaged giant planets (e.g. Delorme et al. 2012; Faherty et al. 2013; Liu et al. 2013b). Furthermore, direct imaging of exoplanets around these low-mass members would be facilitated by their proximity and the fact that younger planets are hotter, and thus brighter (e.g. see Bowler

et al. 2012a; Bowler et al. 2012b; Delorme et al. 2013; Bowler et al. 2013; Naud et al. 2014). For these reasons, a large number of studies were aimed at finding these missing low-mass members and refine our understanding of YMGs (see Torres et al. 2003; Weinberger et al. 2004; Torres et al. 2006; Looper et al. 2007; Shkolnik et al. 2009; Bonnefoy et al. 2009; Lépine & Simon 2009; Schlieder et al. 2010; Looper et al. 2010a; Looper et al. 2010b; Rice et al. 2010; Rodriguez et al. 2011; Kiss et al. 2011; Schlieder et al. 2012a; Schneider et al. 2012a; Faherty et al. 2012; Shkolnik et al. 2012; Delorme et al. 2012; Schlieder et al. 2012b; Malo et al. 2013; Faherty et al. 2013; Weinberger et al. 2013; Moór et al. 2013; Rodriguez et al. 2013; Liu et al. 2013b; Hinkley et al. 2013; Schneider et al. 2014; Kraus et al. 2014; Gagné et al. 2014c; Bonnefoy et al. 2014; Gagné et al. 2014a; Malo et al. 2014a; Riedel et al. 2014; Malo et al. 2014b; Manjavacas et al. 2014; Gagné et al. 2014b; Zapatero Osorio et al. 2014; Mamajek & Bell 2014).

The identification of later-type members of nearby YMGs is a challenging task in the absence of reliable parallax and radial velocity (RV) measurements since their members are spread on large regions of the celestial sphere. Furthermore, obtaining parallax and RV measurements for such faint targets is time-consuming. Careful pre-selection of candidates is thus essential to keep the follow-up effort to a manageable size. Efforts have already been made in identifying late-type members in YMGs, notably by selecting X-ray or UV-bright stars (Torres et al. 2008, Rodriguez et al. 2011, Shkolnik et al. 2012) and by comparing their proper motions to those of known members with the convergent point proper motion analysis (CPA; Montes et al. 2001, Rodriguez et al. 2013). However, this method does not use all available measurements (e.g. photometry, magnitude of proper motion, RV and parallax), therefore it generally suffers from a large con-

tamination of field stars that have proper motions similar to those of YMG members by pure chance, as well as cross-contamination between different YMG candidates. In particular, some YMGs such as COL,  $\beta$ PMG and TWA happen to share similar proper motion distributions as viewed from the Earth, which makes it difficult to differentiate their members using only sky position and the direction of proper motion without radial velocity measurements.

To address these problems, Malo et al. (2013) developed the Bayesian Analysis for Nearby Young AssociationNs (BANYAN<sup>1</sup>), a statistical tool based on Bayesian inference, to identify strong K5–M5 candidate members of YMGs primarily from a sample of X-ray bright sources. In addition to proper motion and sky position, this tool takes advantage of  $I_C$  and  $J$  photometry measurements to ensure that candidate members fall in a region of the color-magnitude diagram (CMD) consistent with other YMG members; younger low-mass stars (LMSs) and brown dwarfs (BDs) are inflated and thus brighter than field stars as they are still undergoing gravitational contraction. This approach provides a more robust set of candidates, as well as most probable distance and RV predictions. However, this study is still limited to detecting candidates with spectral types earlier than  $\sim$  M5, and photometric measurements in the  $I_C$  band are required to take CMD information into account. In parallel, Gagné et al. (2014c) presented BANYAN II<sup>2</sup>, a new selection tool based on BANYAN that includes several improvements (e.g. a better modeling of YMGs spatial and kinematic properties and an extensive treatment of contamination and completeness), and is specifically designed to identify  $>$  M5 YMG candidates, by relying on two different CMDs constructed with photometry from the Two Micron All-Sky Survey (2MASS; Skrutskie et al. 2006) and the WISE survey (Wright et al. 2010). This tool was used in Gagné et al. (2014c) to identify 39 new M5–L4 candidate members among known young field LMSs and BDs. Recently, Kraus et al. (2014) identified 129 new K3–M6 strong candidate members of THA by carrying extensive RV measurements of targets selected for having proper motion and CMD positions similar to those of other THA members. Their results indicate that samples based on GALEX (USNO–A2.0 (VizieR catalog II/312 and Martin et al. 2005) or ROSAT (USNO–A2.0 (VizieR catalog IX/29 and Voges et al. 1999) miss candidates later than  $\sim$  M2 at distances beyond  $\gtrsim$  40 pc.

We present here the BANYAN All-sky Survey (BASS), which is the first all-sky, systematic survey for  $\geq$  M5 LMSs and BDs in YMGs. The whole 2MASS and ALLWISE (Kirkpatrick et al. 2014) catalogs outside of the galactic plane ( $|b| > 15^\circ$ ) were cross-matched, yielding proper motions with typical precisions of a few mas yr<sup>-1</sup>. Color-quality cuts as well as the BANYAN II tool were used to select 153 high- and 21 modest-probability candidate members of YMGs, for which near-infrared (NIR) colors are consistent with  $\geq$  M5 spectral types. The BASS survey has already generated a wealth of new discoveries, including a triple M5 + M5 + planetary-mass companion in THA (Delorme et al. 2013; J. Gagné et al., in preparation), an M5 + L4 host–planet system candidate member of THA (É. Artigau et al., in preparation), a new L-type candidate member of TWA (Gagné et al. 2014a) and a new low-gravity L4 $\beta$  BD candidate member of

ARG (Gagné et al. 2014b). A NIR and optical spectroscopic follow-up of all candidates that will be presented here is undergoing; first results were presented in Gagné et al. (2013) and more will be presented in a subsequent paper (J. Gagné et al., in preparation).

In Section 2, we detail our method for cross-matching the 2MASS and ALLWISE catalogs, which we follow by a description of the various color-quality cuts applied, and how we use the BANYAN II tool to select candidates members of YMGs (Section 3). In Section 4, we present all information available in the literature for the BASS catalog, which we used to update the membership probability when relevant. In Section 5, we evaluate the recovery rate of the BASS sample for known  $\geq$  M5 candidate members and bona fide members of YMGs. We then present various characteristics of the updated BASS catalog in Section 6. In Section 7, we search for new common proper motion pairs among our sample, and we tentatively investigate mass segregation in Section 8. Conclusion are presented in Section 9. The Low-Priority BASS (LP-BASS) sample, consisting of objects only marginally redder than field dwarfs, is presented in Appendix, along with our full input sample of 98 970 potential close-by  $\geq$  M5 dwarfs.

## 2. CROSS-MATCHING THE 2MASS AND ALLWISE CATALOGS

Cross-matching the 2MASS and ALLWISE catalogs ( $\sim$  470 million and  $\sim$  750 million entries respectively) without the use of significant computational resources is a challenge that must be tackled in a strategic way. Fortunately, the NASA Infrared Science Archive (IRSA<sup>3</sup>; Groom et al. 2010) provides useful tools to achieve this. In a first step, we have built two distinct queries for the 2MASS and ALLWISE catalogs to target only potential nearby  $\geq$  M5 dwarfs. We start from spectral type-color relations described in Pecaut & Mamajek (2013), Kirkpatrick et al. (2011) and Dupuy & Liu (2012) to select only targets that have NIR colors consistent with  $\geq$  M5 spectral types, which we subsequently relax to include all currently known young dwarfs in the same range of spectral types (see Gagné et al. 2014c for an extensive list of known young LMSs and BDs in the field). We target only regions of the sky located more than 15 degrees away from the galactic plane, require that measurements of  $J$ ,  $H$ ,  $K_S$ ,  $W1$  and  $W2$  photometry have a reasonable quality, and that no contamination or saturation flags are problematic. We also reject sources spatially resolved in 2MASS but not in ALLWISE. In the Appendix, we list the requirements in the form of two Structured Query Language (SQL) statements that were used to perform all-sky IRSA queries, which correspond to<sup>4</sup>:

- The absolute galactic latitude  $|b|$  of both 2MASS and ALLWISE counterparts respect  $|b| > 15^\circ$ .
- $J > 2$ ,  $H > 2$ ,  $K_S > 2$ ,  $W1 > 2$  and  $W2 > 2$ .
- $0.506 < J - H < 2$ ,  $0.269 < H - K_S < 1.6$  and  $0.168 < W1 - W2 < 2.5$ .
- $W1 - W2 < (0.96 \cdot (W2 - W3) - 0.96)$  if  $W3$  is detected with  $\text{SNR} > 5$  and not saturated (Kirkpatrick et al. 2011).

<sup>3</sup> Available at <http://irsa.ipac.caltech.edu/>

<sup>4</sup> See the column descriptions of the 2MASS User's Guide [http://www.ipac.caltech.edu/2mass/releases/allsky/doc/sec2\\_2a.html](http://www.ipac.caltech.edu/2mass/releases/allsky/doc/sec2_2a.html) and the ALLWISE User's Guide [http://wise2.ipac.caltech.edu/docs/release/allwise/expsup/sec2\\_1a.html](http://wise2.ipac.caltech.edu/docs/release/allwise/expsup/sec2_1a.html) for additional information on the keywords.

<sup>1</sup> Publicly available at <http://www.astro.umontreal.ca/~malo/banyan.php>.

<sup>2</sup> Publicly available at <http://www.astro.umontreal.ca/~gagne/banyanII.php>.

- If a **2MASS** counterpart is identified in the **AllWISE** catalog, it must be at least at an angular distance  $0''.3$  from the **AllWISE** coordinates (i.e., to reject low proper motion objects) and respect  $0.153 < K_S - W1 < 2$  in addition to the **2MASS** color cuts described above.
- The blue magnitude  $B$ , which is either the Johnson  $B_J$  magnitude of a *Tycho 2* (Høg et al. 2000) counterpart, or the photographic blue magnitude of a *USNO-A2.0* (Monet 1998) counterpart of the **2MASS** object (**B\_M\_OPT** keyword) is either undetected or has  $B - J \geq 4.048$ .
- The red or visible  $VR$  magnitude, which is either the Johnson  $V_J$  magnitude of a *Tycho 2* counterpart, or the photographic red magnitude of a *USNO-A2.0* (VizieR catalog *I/252*) counterpart of the **2MASS** object (**VR\_M\_OPT** keyword) is either undetected or has  $VR - J \geq 2.63$  and  $B - VR \geq 1.3$ .
- At least two **2MASS** bands have excellent (A) or good (B) photometric quality flags.
- No **2MASS** band has a poor (D, E or F) or undetected (X or U) quality flags.
- The **AllWISE** photometric quality flags of the  $W1$  and  $W2$  bands are either excellent (A) or good (B).
- The angular distance between the object and its closest neighbor is at least  $6''.4$  in **2MASS**, to ensure that they are resolved in **AllWISE**.
- There are less than 0.2% of saturated pixels in the profile fitting regions of both the  $W1$  and  $W2$  bands in **AllWISE**.
- The source is detected in the  $W1$  and  $W2$  **AllWISE** bands with a statistical significance larger than  $5\sigma$ .
- The reduced  $\chi^2$  of the profile fits for the  $W1$  and  $W2$  **AllWISE** bands both respect  $\chi^2 < 5$ .
- The **2MASS** read flags do not contain 0 (no detection in any band), 6 (not detected in one band) or 9 (nominally detected in one band because of confused regions) for any band.
- The **2MASS** blend flag is 1 (only one component was fit simultaneously for photometry) for all bands.
- The **2MASS** contamination flag is 0 (not contaminated) for all bands.
- The **2MASS** extragalactic contamination flag is 0 (resolved and not extended).
- The **2MASS** minor planet flag is 0 (not associated with a known solar system object).
- The **AllWISE** contamination flags of the  $W1$  and  $W2$  bands do not correspond to potentially spurious detections (D, due to a diffraction spike; P, due to detector persistence; H, due to the scattered light of a bright nearby source; or O, due to an optical ghost caused by a nearby bright source).

- The **AllWISE** extended flag is either 0 (consistent with a point source) or 1 (goodness-of-fit of the profile fitting is larger than 3 in at least one band).

These queries generated two lists: 2 762 191 objects from **2MASS** and 76 883 849 objects from **AllWISE**. To avoid obtaining very large output file sizes, we downloaded only designations, RA and DEC positions, as well as **2MASS** unique identifiers at this stage (keyword **CNTR** in the **2MASS** catalog, and **TMASS\_KEY** in the **AllWISE** catalog; the **IRSA** team already identified **2MASS-AllWISE** cross-matches within  $3''$ ). We then locally rejected all objects located in the following star-forming regions to avoid heavily reddened contaminants : Orion ( $5h29m < RA < 5h41m$  and  $-06^\circ37' < DEC < -02^\circ25'$ ; Béjar et al. 1999), Taurus ( $3h50m < RA < 5h15m$  and  $15^\circ < DEC < 32^\circ$ ; Luhman 2004), Chamaeleon ( $10h45m < RA < 11h30m$  and  $-78^\circ30' < DEC < -76^\circ$ ; Luhman 2007; Alves de Oliveira et al. 2012) and Upper Scorpius ( $15h35m < RA < 16h45m$  and  $-30^\circ < DEC < -21^\circ$ ; Dawson et al. 2011). We subsequently counted the number of **2MASS** neighbors in a  $3'$  radius around each target in the **2MASS** subset, and rejected all those with more than 71 neighbors to avoid densely populated regions. This number was chosen so that none of the known young brown dwarfs in the field and outside of the galactic plane were rejected. This cut down the number of **2MASS** targets to 2 178 389. We then locally cross-matched the unique **2MASS** identifiers of both catalogs to construct list A, consisting of 169 934 **2MASS** sources which already had an **AllWISE** counterpart identified in the latter catalog. The remaining unmatched 2 008 455 **2MASS** sources, as well as the 75 478 161 **AllWISE** sources with null **2MASS** keys, were saved as lists B and C, respectively. **AllWISE** sources with non-null **2MASS** entries that were not cross-matched this way were rejected, since they must have failed at least one of the **2MASS** constraints described above.

We created preliminary cross-matches by identifying the closest **AllWISE** entry in List C to each **2MASS** entry in list B. A total of 2 001 246 of those preliminary matches were separated by distances larger than  $25''$  (equivalent to a proper motion  $> 2.2'' \text{ yr}^{-1}$ ) or had  $K_S - W1 < 0.153$  or  $K_S - W1 > 2$ , and were rejected. For each **2MASS** component of the remaining 7 209 pairs (separated by angular distances of  $\delta$ ), we subsequently downloaded all **AllWISE** entries within  $\delta$ , and verified that the closest entry with a null **2MASS\_KEY** corresponded to our preliminary match. We also verified that the **2MASS\_KEY** was not assigned to any other nearby **AllWISE** source. This step has rejected 767 objects. In a final step, we downloaded all **2MASS** and **AllWISE** entries in a radius  $\delta+3''$  around every **AllWISE** component of the 5 876 remaining pairs, and removed all **IRSA**-identified cross-matches. We use a search radius of  $\delta+3''$  in this step to ensure that we retrieve all **2MASS-AllWISE** matches in the **AllWISE** catalog in a radius  $\delta$ , since those matches can be separated by up to  $3''$ . We then verified that the closest **2MASS** entry among those objects not already cross-matched by **IRSA** corresponded to the **2MASS** component of the preliminary pairs: this filter rejected 2 367 objects. The 3 509 pairs that survived all these selection criteria were added to List A. We then used **2MASS** and **AllWISE** astrometry to determine proper motions for all 173 443 objects in this supplemented List A, and rejected the 74 473 sources with a total proper motion lower than  $30 \text{ mas yr}^{-1}$ , or with a total proper motion measurement at  $< 5\sigma$ , to reject extragalactic contaminants and red giants.



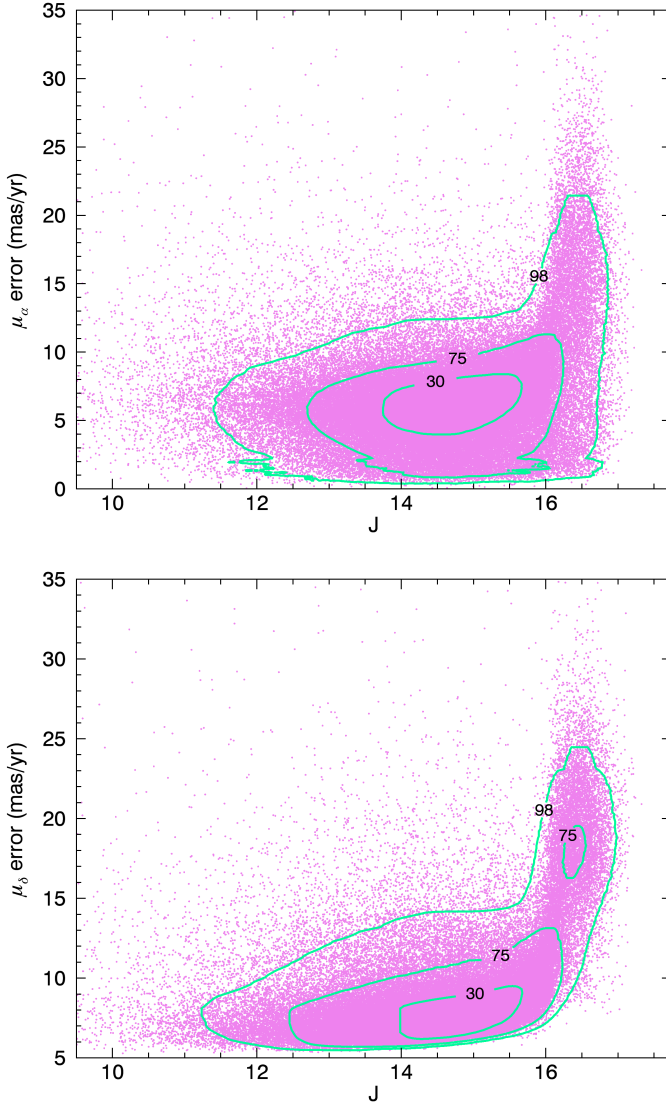


FIG. 1.— Proper motion precision as a function of *2MASS* *J* magnitude in List A (pink points; see Section 2). Green contour lines respectively include 10%, 75% and 98% of all data points. In the case of bright objects ( $J < 16$ ), typical precisions are 3–10 mas yr<sup>−1</sup> ( $\mu_\alpha \cos \delta$ ) and 5–10 mas yr<sup>−1</sup> ( $\mu_\delta$ ), whereas they can go down to  $\sim 25$  mas yr<sup>−1</sup> for fainter objects.

Proper motions were calculated directly from entries in both the *2MASS* and *AllWISE* catalogs. The right ascension (RA) and declination (DEC) entries were used for the astrometric position of both catalogs; the *SIGRA* and *SIGDEC* entries of *AllWISE* were used as a measurement error, and the *ERR\_MAJ* ( $\sigma_{\text{MAJ}}$ ), *ERR\_MIN* ( $\sigma_{\text{MIN}}$ ) and *ERR\_ANG* ( $\sigma_\theta$ ) entries of the *2MASS* catalog were projected back to errors on right ascension ( $\sigma_\alpha$ ) and declination ( $\sigma_\delta$ ) with :

$$\sigma_\alpha = \sqrt{(\sigma_{\text{MAJ}} \sin \sigma_\theta)^2 + (\sigma_{\text{MIN}} \cos \sigma_\theta)^2} \cdot \cos \delta \quad (1)$$

$$\sigma_\delta = \sqrt{(\sigma_{\text{MAJ}} \cos \sigma_\theta)^2 + (\sigma_{\text{MIN}} \sin \sigma_\theta)^2} \quad (2)$$

where  $\delta$  is the *2MASS* declination. The epochs corresponding to these astrometric measurements were taken from the *JDATE* and *WIMJDMEAN* entries in the respective catalogs. *WIMJDMEAN* corresponds to the mean epoch of all *AllWISE* exposures taken in the *W1* band. The uncertainty on

the *2MASS* epoch is taken to be 30 s, as described in the *2MASS User's Guide*, and the uncertainty on the *AllWISE* epoch is taken in a conservative way as half of the maximal distance between all exposures (from the *WIMJDMAX* and *WIMJDMIN* entries). We analytically propagated all measurement errors (astrometric and temporal) of both catalogs, assuming they were all independent, to obtain the measurement errors on our *2MASS–AllWISE* proper motions. The positional accuracy of the *2MASS* and *AllWISE* catalogs vary from  $\sim 0''.05$  for bright sources ( $J \lesssim 14$ ), to  $0''.1$ – $0''.4$  (*2MASS*) and  $0''.06$ – $0''.15$  (*AllWISE*) for fainter sources. The final set of 98 970 objects contains probable nearby  $> M5$  dwarfs with measurements of proper motion above 30 mas yr<sup>−1</sup>. We list this sample in the Appendix, since this sample provides a great opportunity to study the kinematics of LMSs and BDs in the solar neighborhood. In Figure 1, we show that typical measurement errors on proper motions are 5–10 mas yr<sup>−1</sup> for bright objects ( $J < 16$ ), or 5–25 mas yr<sup>−1</sup> for fainter objects.

We cross-matched our input sample with the Initial Gaia Source List (*VizieR* catalog *I/324/igs13*) to obtain proper motions from the *UCAC3* (*VizieR* catalog *I/315*; Zacharias et al. 2009) and the *Guide Star Catalog* (GSC; *VizieR* catalog *I/305* and Lasker et al. 2008), and present in Figure 2 a comparison to the proper motions we derived from *2MASS–AllWISE*. We find reduced  $\chi^2$  values of 1.27 and 1.03 for  $\mu_\alpha \cos \delta$  and  $\mu_\delta$ , respectively, which indicates that our measurement errors are representative of the differences between our proper motions and those in the catalogs mentioned above. However, there are a few cases where the literature proper motions are significantly discrepant from the *2MASS–AllWISE* measurements. We investigated the 25/3 873 worst cases in *UCAC3* where either  $\mu_\alpha \cos \delta$  or  $\mu_\delta$  were discrepant by more than 300 mas yr<sup>−1</sup>. In 24/25 cases, we found other measurements in the literature that matched the *2MASS–AllWISE* measurement within a few  $\sigma$  (typically less than  $1\sigma$ ), indicating that the *UCAC3* measurement might be at fault. The other case (*2MASS* J17274680+5200079) corresponds to a  $6''.5$  binary which is barely above the angular resolution of *AllWISE* ( $6''.1$  in the *W1* band and  $6''.4$  in the *W2* band). Rodríguez et al. (2013) indicate that they observe a small systematic distortion ( $< 15$  mas yr<sup>−1</sup>) for their  $\mu_\alpha \cos \delta$  measurements from *2MASS–WISE* as a function of galactic latitude. They propose a correction factor, which would increase our reduced  $\chi^2$  value to 1.27 to 1.82. This indicates that such a distortion is not clearly seen in our sample, and we thus choose not to include it in the present work. We conclude that the proper motions derived from *2MASS–AllWISE* are reliable and will use only those measurements of proper motion for the remainder of this work. This will ensure that our selection criteria are more homogeneous, which will be helpful in an eventual characterization of the young population in the *BASS* survey.

### 3. IDENTIFICATION OF CANDIDATE YOUNG MOVING GROUP MEMBERS

We used *BANYAN II* (Gagné et al. 2014c) to compute the membership probability of all 98 970 potential close-by  $\geq M5$  dwarfs identified in the previous section (List A). The *BANYAN II* tool takes sky position, proper motion and *2MASS* and *AllWISE* photometry as inputs and determines, using a naive Bayesian classifier, the membership probability that an object belongs to seven YMGs (TWA,  $\beta$ PMG, THA, COL, CAR, ARG, ABDMG) and the field population, which



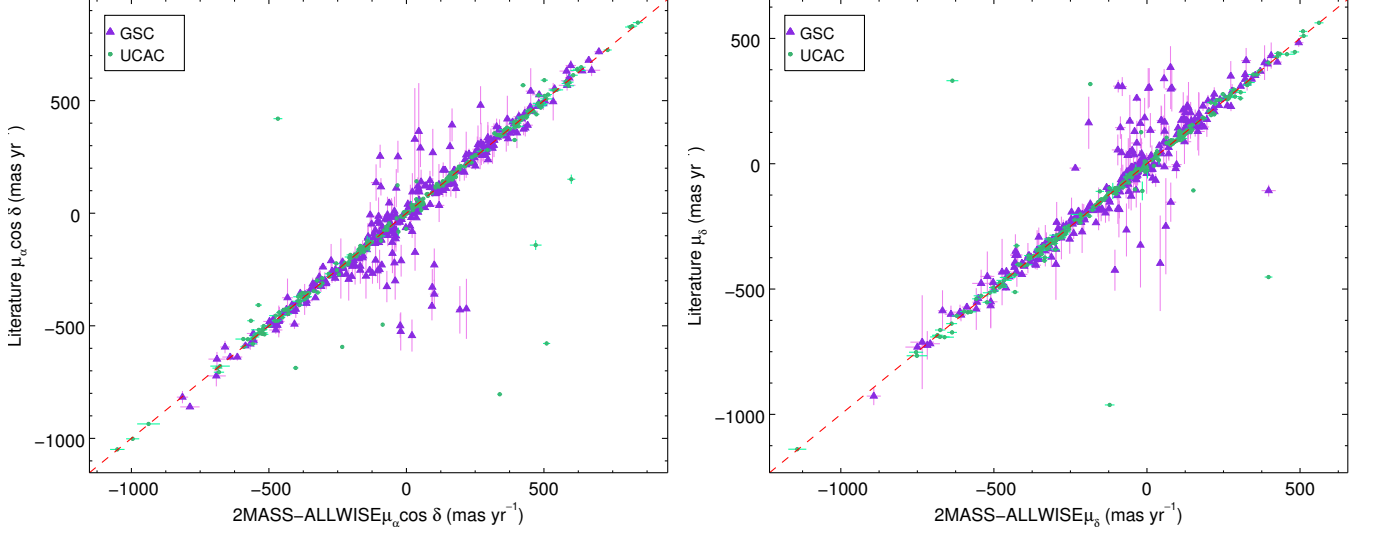


FIG. 2.— Comparison between proper motions determined from the *2MASS* and *ALLWISE* datasets and measurements in the literature, for a random subset of the input sample of 98 970 objects. We only display 500 random objects per bin of  $\sim 200 \text{ mas yr}^{-1}$ , to improve visibility. Measurements from the literature were obtained from the Initial Gaia Source List (*VizieR* catalog *I/324/igs13*) which cross-matches *UCAC3* (Zacharias et al. 2009; green circles) and the *Guide Star Catalog* (Lasker et al. 2008; purple triangles). The reduced chi-square values for  $\mu_\alpha \cos \delta$  and  $\mu_\delta$  are 1.27 and 1.03, respectively.

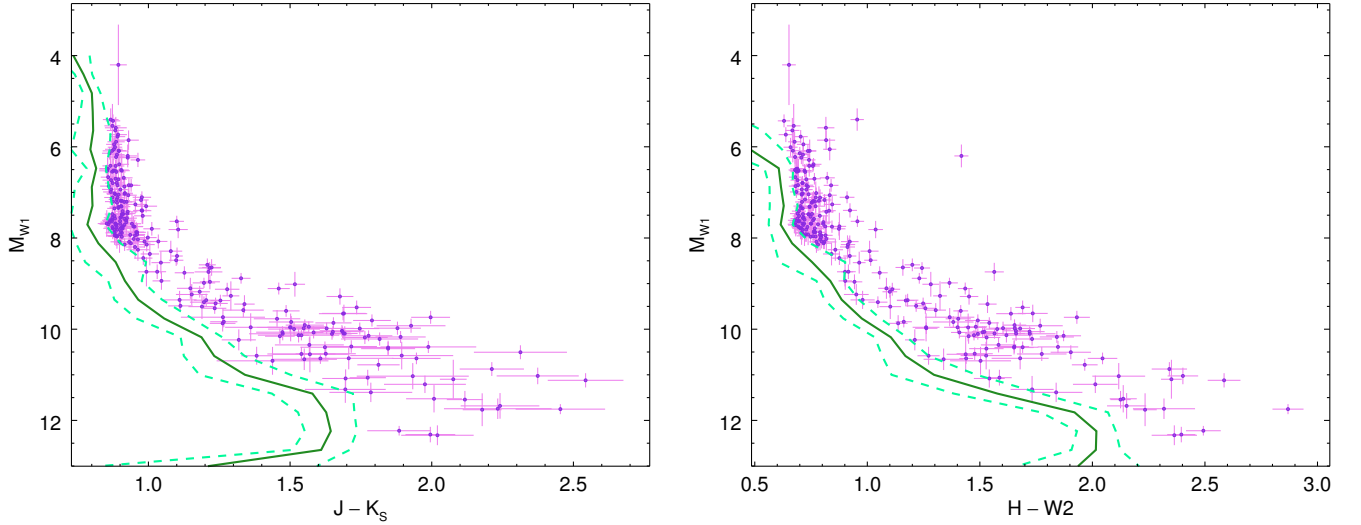


FIG. 3.— Positions of all objects in the *BASS* sample in two different CMDs (purple points), compared with the field sequence (thick green line) and its scatter (dashed green lines). We used the statistical distances of the most probable hypothesis from the *BANYAN II* tool to compute absolute magnitudes. The positions of all *BASS* candidates are consistent with them being young objects brighter and/or redder than the field sequence.

constitutes our eight hypotheses. Probability Density Functions (PDFs) are computed for every hypothesis and on each point of a regular  $500 \times 500$  grid of distances and RVs spanning 0.1 to 200 pc and  $-35$  to  $35 \text{ km s}^{-1}$  respectively, by comparing galactic positions ( $XYZ$ ) and space velocities ( $UVW$ ) to the spatial and kinematic model (SKM) of the respective hypotheses, as well as comparing *2MASS* and *ALLWISE* magnitudes to a photometric model. All measurement errors are propagated and considered in this comparison. SKMs of YMGs were built by fitting 3-dimensional ellipsoids, with unconstrained axes orientations, over the population of bona fide members with signs of youth as well as parallax and RV measurements (see Malo et al. 2013 and Gagné et al. 2014c for a complete list). For the field hypothesis, similar ellip-

soids were fitted to synthetic objects drawn from the Besançon galactic model (A. C. Robin et al. in preparation, Robin et al. 2012) at distances of  $< 200$  pc. The photometric model consists of an old and a young field sequence in two CMD diagrams: absolute  $W1$  as a function of  $H - W2$  and absolute  $W1$  as a function of  $J - K_s$ . The positions of maxima and characteristic widths of the resulting posterior PDFs yield a statistical distance and RV prediction, assuming the object fulfills the respective hypothesis. The same PDFs are marginalized to a final probability by numerically integrating them along the whole grid. Optionally, parallax and RV measurements can be included to derive a more robust probability. In these cases, the corresponding dimension of the marginalization grid is eliminated. The Prior probabilities in the Bayesian classifier are set to the respective population estimates of each hypothe-

ses, considering the magnitude of proper motion and galactic latitude of the object. Additionally, equal-luminosity binary hypotheses for the field and all YMGs are supplemented to our set of hypotheses, where the CMDs are shifted up by 0.75 magnitudes. Objects for which the binary hypothesis has a higher probability will be flagged as potential binaries, and only the binary hypotheses will be used when we analyze known binary systems. A naive Bayesian classifier implicitly considers that all input parameters are independent, which is generally not the case here. Using such an analysis with dependent input parameters will generally provide a good classification, however the Bayesian probability will be biased and thus not interpretable in an absolute way (e.g. a set of candidates with a Bayesian probabilities of 90% will not necessarily include a fraction of contaminants equal to 10%; Hand & Yu 2001, Russek et al. 1983). To address this, Gagné et al. 2014c performed a Monte Carlo analysis using all SKM and photometric models described above to estimate the field contamination probability as a function of Bayesian probability for different hypotheses. They find that Bayesian probabilities are generally pessimistic, except for YMGs which are most subject to contamination (ARG, ABDMG,  $\beta$ PMG and COL) when no parallax measurement is included. When a parallax measurement is included, the contamination probability becomes very low ( $\lesssim 20\%$  when the Bayesian probability is larger than  $\sim 10\text{--}40\%$  depending on the YMG). These results provide a translation for the Bayesian probability output by **BANYAN II** to an expected contamination rate. Gagné et al. (2014c) showed that bona fide members within  $< 1\sigma$  of their YMG's SKM all have a Bayesian probability  $> 95\%$  associated with a membership to their respective YMG, whereas peripheral ( $1\text{--}2.5\sigma$ ) bona fide members have a Bayesian probability between  $10\text{--}95\%$ . For more details about the **BANYAN II** tool, the reader is referred to Gagné et al. (2014c).

After applying **BANYAN II** to our input sample (list A), we rejected all objects with a Bayesian probability  $< 10\%$  of being a member to a YMG, or with an estimated contamination rate  $> 50\%$ . At this point we are left with 983 candidates. We used statistical distances of the most probable hypotheses to place all candidates in the two CMDs described above, and rejected all candidates that did not have NIR colors at least  $1\sigma$  redder than the field sequence. These filters cut down the candidate list to 273 objects. Another set of 275 candidates located to the right of the field sequence by an amount less than  $1\sigma$  were used to build the low-priority **BASS** catalog (**LP-BASS**) which is discussed in the Appendix of this paper. The **AllWISE** catalog includes **WISE** observations that were performed in its warm phase, hence in some cases, the measurement of  $W1$  or  $W2$  can be saturated. To avoid overlooking such saturated targets, we repeated all steps described above using the **WISE** catalog instead of **AllWISE**, and supplemented our sample with the additional 26 objects uncovered this way (96 in the case of **LP-BASS**). We subsequently used the **IRSA dust extinction tool**<sup>5</sup> to remove 9 objects displaying extinction larger than 0.4 mag, potentially corresponding to distant contaminants reddened by interstellar matter in our line of sight. Another 3 objects listed in the the **2MASS extended sources** catalog (**VizieR** catalog **VII/233/xsc**) were rejected. In a final step, we visually inspected all **SDSS**, **DSS**, **2MASS** and **AllWISE** acquisition images to flag any object with a suspicious shape or evidence of interstellar absorption in the surrounding  $5'$ . No such occurrence was found, which indicates the filters described above were efficient in preventing such contaminating objects. The resulting **BASS** catalog is presented in Table 2. We divide the sample in two sections: those with a contamination probability lower than  $15\%$  are grouped in a *High Probability* section, whereas those with a contamination probability between  $15\text{--}50\%$  are grouped in the *Modest Probability* section.

TABLE 1  
EXPECTED COMPLETENESS OF THE **BASS** SURVEY.

YMG Name	$ b  \leq 15^\circ$	$\mu \leq 30 \text{ mas yr}^{-1}$	SFRs <sup>a</sup>	SFRs or $ b  \leq 15^\circ$ or $\mu \leq 30 \text{ mas yr}^{-1b}$	Contamination $\geq 50\%$	Expected Completeness
ARG	42.1%	0.5%	0.6%	42.6%	89.6%	6.0%
COL	15.7%	23.4%	1.8%	36.4%	59.7%	25.6%
$\beta$ PMG	25.2%	0.8%	3.4%	28.3%	60.0%	28.7%
ABDMG	20.7%	1.1%	1.6%	22.8%	59.6%	31.2%
CAR	41.2%	2.7%	0.1%	42.9%	9.9%	51.4%
TWA	19.7%	0.4%	0%	20.0%	10.3%	71.8%
THA	$< 0.1\%$	$< 0.1\%$	0%	$< 0.1\%$	10.0%	90.0%

<sup>a</sup> Expected fraction of members aligned with Orion, Taurus, Chamaeleon and Upper Scorpius (see Section 2).

<sup>b</sup> Filters on position and proper motion are not independent.

In Table 1, we present the fraction of members in each moving group that would fail our galactic plane and proper motion filters, assuming that our SKM models are accurate. We obtained these quantities by drawing a million synthetic objects from a gaussian random distribution represented by each SKM and assessing what fraction fails each filter. We used the estimated recovery rate of the **BANYAN II** tool for each YMG (see Gagné et al. 2014c) corresponding to our tolerated field contamination of  $< 50\%$  and combined all these sources of incompleteness to estimate that the **BASS** sample is complete at the  $6\text{--}90\%$  level in the range of spectral types considered

here, depending on the YMG in question. The YMGs that would benefit the most from a search within the galactic plane are ARG and CAR, and to a lesser extent  $\beta$ PMG, ABDMG and TWA. However, such a survey would present a significant challenge for two reasons ; (1) a cross-match between the **2MASS** and **AllWISE** catalogs would require the use of powerful algorithms because of crowded regions; and (2) a new free parameter would have to be added to the analysis, describing the effect of reddening by interstellar medium on the CMD sequence of field stars (e.g. this effect could be represented by a reddening vector of unknown amplitude in both CMDs that are used in the **BANYAN II** tool). We note that even if those two hurdles would be overcome, we expect the field contamination to remain very high within the galactic plane, unless

<sup>5</sup> Available at <http://irsa.ipac.caltech.edu/applications/DUST/>

the survey benefits from RV and parallax measurements for a large number of objects. The only YMG which is significantly affected by our low proper motion cut is COL. Since this filter serves the main purpose of rejecting distant extragalactic and red giant contaminants, starting from a sample of targets with distance measurements would allow relaxing this filter and accessing to a larger number of COL candidates. The final major obstacle to identify efficiently a large number of candidate members of ARG, COL,  $\beta$ PMG and ABDMG is the low recovery rate intrinsic to a naive Bayesian classifier in the situation where no information is known on the RV and distance of the input sample. It could be expected that adopting a more complex method, which could for example take account of the

dependency of input parameters, would help to draw the most possible information from a sample without RV and distance measurements. However, [Hand & Yu \(2001\)](#) suggest otherwise by demonstrating that a naive Bayesian classifier performs much better than could be expected in these conditions. This would leave only three foreseeable options to attack this aspect of our survey completeness; (1) allow for significantly more contaminants in our sample and perform an extensive spectroscopic follow-up; (2) start from a sample that includes RV and parallax measurements; or (3) identify new readily-accessible observables, such as new filters in color-color diagrams, that could distinguish YMG members from field interlopers.

TABLE 2  
ALL-SKY SEARCH FOR > M5 CANDIDATES IN YOUNG MOVING GROUPS.

2MASS Designation	Estim. SpT	2MASS			AllWISE		$\mu_{\alpha} \cos \delta$ (mas yr <sup>-1</sup> )	$\mu_{\delta}$ (mas yr <sup>-1</sup> )	Member- ship	Bayesian Prob. (%)	Contamination Prob. (%)
		<i>J</i>	<i>H</i>	<i>K<sub>S</sub></i>	W1	W2					
Candidates with a High Probability											
00011217+1535355	L3.2	15.52	14.51	13.71	12.97	12.54	139.6 ± 7.8	−183.5 ± 11.8	ABDMG	79.1	1.6
00040288-6410358	L2.5	15.79	14.83	14.01	13.41	12.96	77.7 ± 3.0	−56.1 ± 8.4	THA <sup>a</sup>	99.9	< 0.1
00041589-8747254	M5.7	12.90	12.20	11.86	11.65	11.41	77.3 ± 2.0	−29.9 ± 9.2	THA	55.4	< 0.1
00065794-6436542	M6.9	13.39	12.66	12.17	11.74	11.42	92.7 ± 3.1	−71.0 ± 7.3	THA <sup>a</sup>	99.9	< 0.1
00111532-3756553	M5.7	12.15	11.60	11.22	11.02	10.79	105.7 ± 5.0	−77.4 ± 7.4	THA	80.2	< 0.1
00182834-6703130	M9.6	15.46	14.48	13.71	13.19	12.80	83.6 ± 2.9	−65.0 ± 9.3	THA <sup>a</sup>	99.8	< 0.1
00191296-6226005	M9.7	15.64	14.62	13.96	13.38	12.96	66.1 ± 2.9	−50.6 ± 8.4	THA	99.5	< 0.1
00212774-6351081	M4.0	11.02	10.48	10.11	9.91	9.66	83.0 ± 2.9	−57.6 ± 7.2	THA	99.8	< 0.1
00235732-5531435	M4.5	11.11	10.55	10.24	10.07	9.87	92.3 ± 3.4	−67.7 ± 7.4	THA <sup>a</sup>	99.5	< 0.1
00305785-6550058 <sup>b</sup>	M2.1	9.82	9.24	8.95	8.79	8.61	70.3 ± 2.9	−51.9 ± 8.7	THA	99.1	< 0.1
Candidates with a Modest Probability											
00160844-0043021	L4.0	16.33	15.23	14.54	13.84	13.39	138.3 ± 9.9	−33.7 ± 14.2	BPMG	18.8	36.4
00192626+4614078	M5.9	12.60	11.94	11.50	11.28	11.02	119.6 ± 6.1	−82.5 ± 6.9	ABDMG	53.3	17.5
00274534-0806046	M5.3	11.57	10.97	10.61	10.41	10.18	111.5 ± 7.0	−59.9 ± 6.7	BPMG	45.6	35.1
00390342+1330170	M5.1	10.94	10.37	10.06	9.84	9.65	109.8 ± 6.8	−96.5 ± 7.0	BPMG	57.9	15.3
00464841+0715177	M8.2	13.89	13.18	12.55	12.09	11.64	97.0 ± 9.2	−60.3 ± 7.3	BPMG <sup>a</sup>	78.5	28.4
00581143-5653326	L6.1	16.78	15.55	14.55	13.76	13.24	197.4 ± 6.2	46.0 ± 12.2	ARG	80.4	32.9
01033203+1935361	L6.2	16.29	14.90	14.15	13.18	12.70	303.0 ± 13.4	16.6 ± 7.2	ARG	31.7	16.9
01525534-6329301	M4.7	10.17	9.60	9.26	9.06	8.84	130.0 ± 3.5	7.0 ± 6.4	BPMG	71.4	22.1
02534448-7959133	M5.4	11.34	10.74	10.38	10.18	9.97	81.7 ± 2.2	90.3 ± 9.3	BPMG	71.8	24.9
03390160-2434059	M3.7	10.90	10.34	9.97	9.72	9.52	56.3 ± 5.7	−12.7 ± 6.0	COL	60.5	32.9

<sup>a</sup> The binary hypothesis is more probable than the single hypothesis (see [Section 3](#)).

<sup>b</sup> Object from the *WISE* catalog rather than *AIWWISE*.

This table is available in its entirety in the online journal. The complete table has 263 rows (239 high probability candidates and 24 modest probability candidates).

#### 4. A LITERATURE SEARCH FOR ADDITIONAL INFORMATION

We searched for any additional information in the literature for all candidates in [Table 2](#) using the *SIMBAD* and *VizieR* web tools. We found 122 objects for which at least one of RV, parallax, spectral type, signs of youth or any other relevant information was available, including 60 known candidates or bona fide members of the YMGs considered here. There are only 4 known bona fide members included in those: *2MASS J00452143+1634446* (ARG; [Zapatero Osorio et al. 2014](#) and [Section 4.2](#)) *2MASS J01231125-6921379* (THA; [Gagné et al. 2014c](#)), *GJ 2022* (ABDMG; [Riedel 2012](#), [Shkolnik et al. 2012](#) and [Riedel et al. 2014](#)), *2MASS J03552337+1133437* (ABDMG; [Faherty et al. 2013](#), [Liu et al. 2013a](#)). We list these 59 objects in [Table 3](#), with an updated Bayesian probability in light of these additional measurements. In [Figure 5](#), we compare the *BANYAN II* statistical predictions for the RV and distance to measurements

found in the literature, and show that the reduced  $\chi^2$  values are 1.32 and 0.84, respectively. This indicates that errors on statistical predictions are representative of the scatter observed here.

##### 4.1. Estimates of Spectral Types

We used *2MASS* and *AIWWISE* *J*, *H*, *K<sub>S</sub>*, *W1* and *W2* magnitudes with the statistical distance associated to the most probable hypothesis from *BANYAN II* to assign a tentative spectral type to all candidates identified here. We used the *Database of Ultracool Parallaxes*<sup>6</sup> ([Dupuy & Liu 2012](#)) to compare the position of each candidate with the corresponding spectral type – magnitude sequence (spanning the M5–T9 range) and derived a PDF in each case as a function of spectral type. We then combined these PDFs in a likelihood analysis,

<sup>6</sup> Available at

[http://www.cfa.harvard.edu/~tdupuy/plx/Database\\_of\\_Ultracool\\_Parallaxes.html](http://www.cfa.harvard.edu/~tdupuy/plx/Database_of_Ultracool_Parallaxes.html)



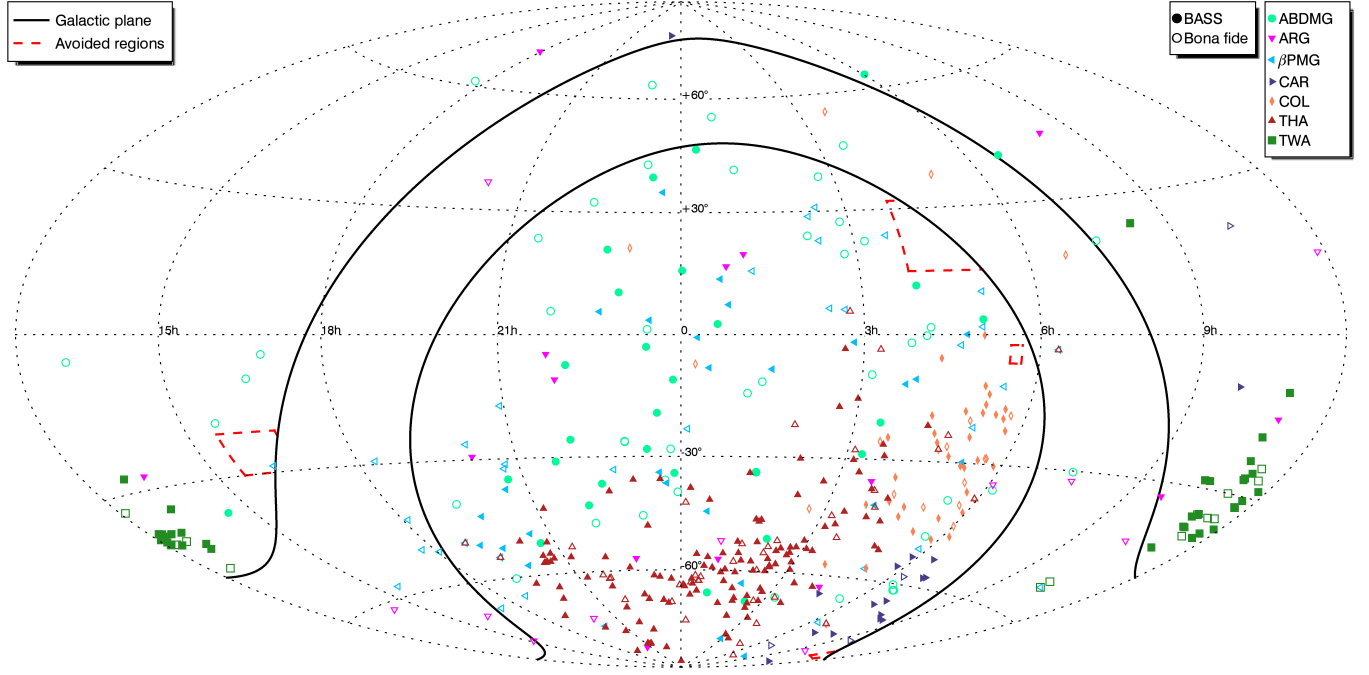


FIG. 4.— Sky position of all **BASS** candidates (filled symbols), compared with currently known bona fide members (open symbols) of each YMG considered here. Thick black lines delimit the galactic plane within  $\pm 15^\circ$  of galactic latitude, and the dashed red lines delimit regions that were avoided in our search for YMG candidates (see Section 2).

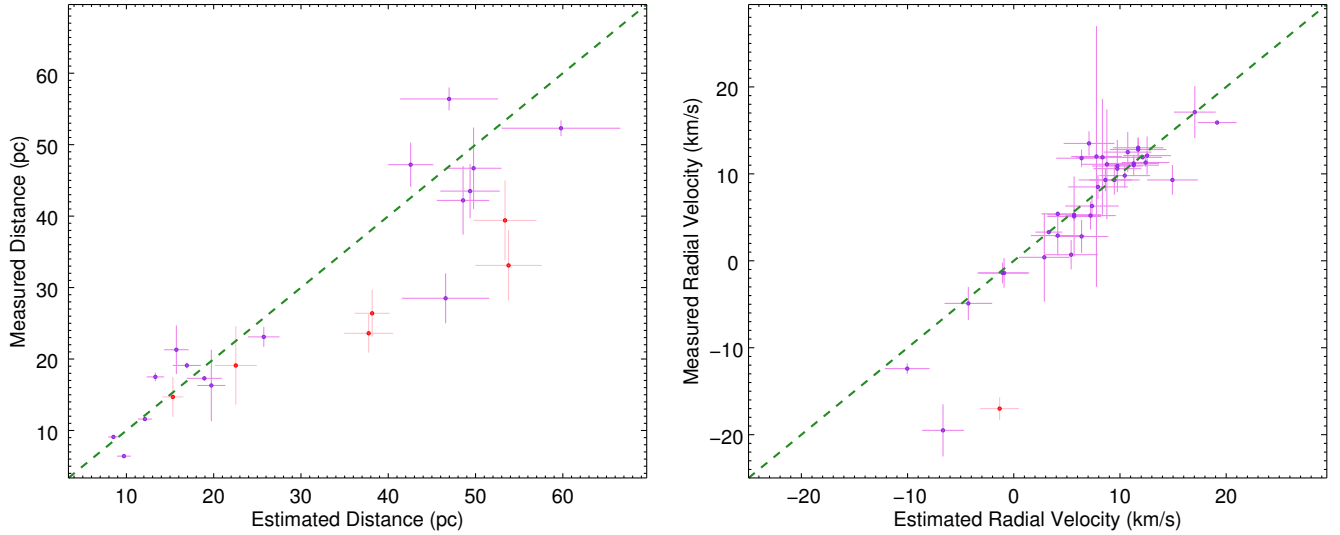


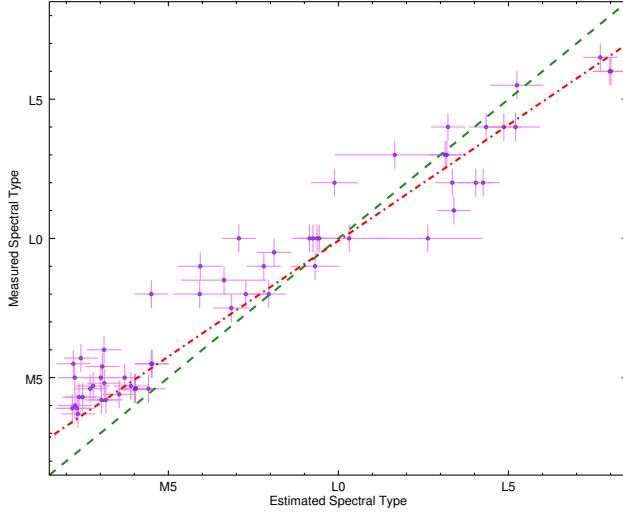
FIG. 5.— Comparison of statistical RV and distance predictions from **BANYAN II** to measurements found in the literature. The dashed green line has a unit slope and intersects with the origin. Measurements which corroborated the most probable hypothesis are displayed in purple, whereas those favoring a different YMG are displayed in red. Measurements which are significantly discrepant and thus rejecting possible YMG memberships are not displayed here.

and used the maximal position of the final PDF to assign a most probable spectral type to each object. In Figure 6, we compare our spectral type estimates to measurements available in the literature and show that these estimates are reliable to within  $\sim 2.5$  subtypes.

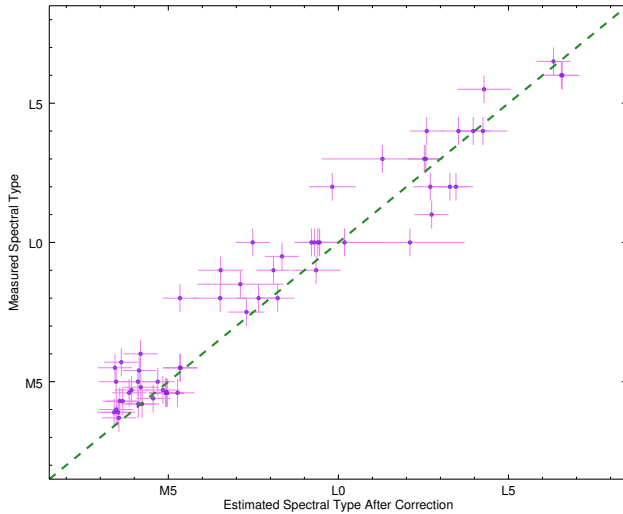
We note a clear trend where we tend to underestimate spectral types for  $< M5$  objects and overestimate those of  $> L5$  objects. We used a linear fit to characterize this systematic trend and obtain a correction for our estimated spectral types:

$$\text{SpT}_{\text{corr}} = 1.64 + 0.81 \cdot \text{SpT}_{\text{estim}}, \quad (3)$$

where 0 corresponds to the M0 spectral type. We used this equation to correct all estimated spectral types listed in Tables 2 and 5. Before the correction, the reduced  $\chi^2$  value for our estimated spectral types is 2.51, and the estimated-measured spectral type differences display a standard deviation of 1.1 subtypes. After the correction, the reduced  $\chi^2$  and standard deviation become 1.0 and 0.8 subtypes, respectively.



(a) Before Correction



(b) After Correction

FIG. 6.— Estimated spectral types obtained from *2MASS* and *AllWISE* photometry as well as statistical distances from *BANYAN II*, compared with measurements available in the literature from optical or NIR spectroscopy. The dashed green line has a unit slope and intersects with the origin. Our estimates are reliable within  $\sim 1.5$  subtype in the M5–L6 range, but tend to overestimate (underestimate) later (earlier) spectral types. To account for this effect, we adjusted a linear correction to the estimated spectral types (red dashed line; top panel). Corrected estimations of spectral types are displayed in the bottom panel.

In Figure 7, we use spectral type measurements when available or estimates of spectral types otherwise to compare the *BASS* sample with current bona fide members in YMGs. This Figure clearly demonstrates that a significant fraction of the *BASS* candidates have a later spectral type than most known members of YMGs, which outlines that we are entering a yet poorly explored mass regime of the YMG population.

#### 4.2. Comments on Individual Objects

In this Section, we present comments on individual objects which deserve further discussion. All those already discussed in Gagné et al. (2014c; see the Reference column in Table 3)

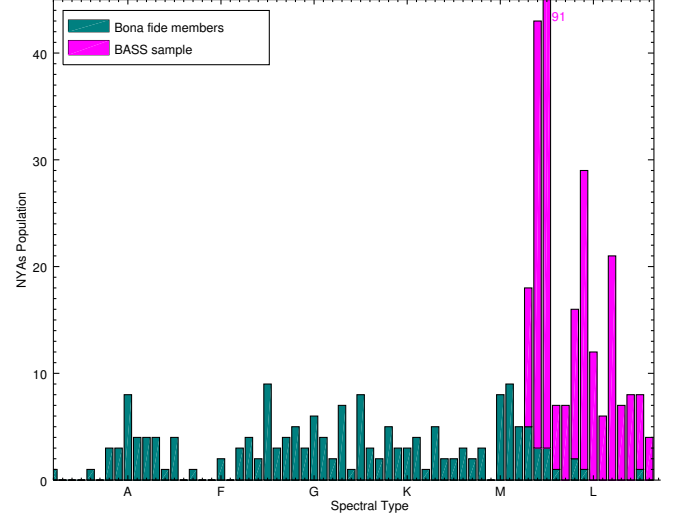


FIG. 7.— Estimated spectral types (violet bars) for the *BASS* sample, compared with the current bona fide population of all YMGs considered here (green bars). The M5 spectral bin has a value of 91: the vertical range has been shortened for clarity. The *BASS* sample targets YMG candidates in a range of spectral types which is yet largely unexplored.

will not be discussed here, unless new information is available.

*2MASS J00390342+1330170* has been identified by Schlieder et al. (2012a) as a candidate member of ABDMG with X-ray and near-UV emission indicative of a young, early-M dwarf, however they do not estimate a spectral type. We find that this object has a Bayesian probability of 84.3% and 7.5% for  $\beta$ PMG and ABDMG, respectively. We thus assign it as a candidate member of  $\beta$ PMG, but we note that there is an expected  $\sim 10\%$  contamination rate from ABDMG to  $\beta$ PMG for such a result (see Gagné et al. 2014c).

*2MASS J00452143+1634446* was reported by Gagné et al. (2014c) as a candidate member of ARG with unusually red NIR colors for its L2 spectral type. Blake et al. (2010) measured a RV of  $3.4 \pm 0.2$  km s $^{-1}$ , and Zapatero Osorio et al. (2014) measured a trigonometric distance of  $17.5 \pm 0.6$  pc, which bring the Bayesian probability of the ARG membership hypothesis to 98.0%. Zapatero Osorio et al. (2014) also derived an isochronal age of 10–100 Myr and detected lithium in its atmosphere. As noted by Zapatero Osorio et al. (2014), all evidence points towards a membership to ARG, hence we propose that this  $\sim 15 M_{\text{Jup}}$  object is a bona fide member of this association.

*2MASS J01033563–5515561* was first identified as a highly probable candidate to THA in early versions of the *BASS* sample. Delorme et al. (2013) used high contrast imaging to search for low-mass companions around *BASS* candidates and demonstrated that this object is in fact an M5+M5, 0''26 tight binary harboring a 12–14  $M_{\text{Jup}}$  substellar companion at a separation of 1''78. They note that the NIR colors of the companion are indicative of a young L-type object, which is consistent with the THA membership. Subsequently, Kraus et al. (2014) and Malo et al. (2014a) independently measured RVs of  $4.0 \pm 2.0$  km s $^{-1}$  and  $7.3 \pm 2.6$  km s $^{-1}$  respectively, whereas the latter independently identifies it as a candidate member of THA. We combined both RV measurements to obtain RV =  $5.2 \pm 1.6$  km s $^{-1}$ . Riedel et al. (2014) measured a trigonometric distance of  $47.2 \pm 3.1$  pc,

in good agreement with our statistical distance of  $42.3 \pm 3$  pc (which is at  $1.1\sigma$  from the measurement). Without using any RV measurement, they argue that its kinematics are more consistent with CAR rather than THA. They also use empirical isochrones for YMGs to show that the system is over-luminous for THA or CAR even when binarity is taken into account, which could mean that it is possibly younger, or an even higher-order multiple system. When not using the RV measurement in **BANYAN II**, we obtain a Bayesian probability of 98.9%, 0.7% and  $2 \cdot 10^{-7}$  for THA, ABDMG and CAR, respectively. The statistical RVs associated to these hypotheses are respectively  $7.2 \pm 2.5$  km s $^{-1}$ ,  $10.8 \pm 1.8$  km s $^{-1}$  and  $14.0 \pm 2.0$  km s $^{-1}$ . Both the measured RVs are consistent with the THA hypothesis (at  $0.7\sigma$ ) and not consistent with CAR (at  $3.0\sigma$ ), which strengthens the THA hypothesis even more. Once we include the RV measurement, the THA hypothesis clearly dominates with a Bayesian probability of 99.9% for THA and  $2 \cdot 10^{-10}$  for CAR. We thus suggest that this system is a bona fide member of THA, since it has all measurements needed to be considered as such (i.e. complete XYZUVW kinematics and signs of youth). This system will be discussed in more details in a subsequent paper (J. Gagné et al., in preparation).

**2MASS J01243060–3355014 (GJ 2022 B)** was identified by Jao et al. (2003) as a co-moving companion to the tight 1.''8 M4+M4 binary **GJ 2202 AC**. Shkolnik et al. (2009) used the X-ray emission and low K I EW of the latter to constrain its age between 40–300 Myr, and Shkolnik et al. (2012) measured a trigonometric distance of  $25.1 \pm 1.0$  pc and a RV of  $18.3 \pm 1.5$  km s $^{-1}$  for **GJ 2022 B**. They use this information to identify this object as a new bona fide member of ABDMG. Riedel et al. (2014) subsequently measured a trigonometric distance of  $25.8 \pm 1.4$  pc; we combined both distance measurements in an error-weighted average to obtain  $25.3 \pm 0.8$  pc. We find that the ABDMG membership, distance and RV measurements are all consistent with our results from **BANYAN II**; the predicted RV of  $18.3 \pm 2.0$  km s $^{-1}$  is consistent with the measurement, and the statistical distance of  $26.1 \pm 1.6$  pc is at  $< 1\sigma$  of the combined distance measurements. Including youth, RV, distance and spectral types in our analysis yields a membership probability of 99.98% for the ABDMG hypothesis, associated with a field contamination probability of  $< 0.1\%$ . This is consistent with the conclusions of Shkolnik et al. (2012) and Riedel et al. (2014) that this system is a bona fide member of ABDMG. We note that Shkolnik et al. (2012) refer to the wide companion as GJ 2022 C, whereas Jao et al. (2003) and Riedel et al. (2014) refer to it as GJ 2022 B. We adopt the latter to preserve historical nomenclature, as proposed by Riedel et al. (2014).

**2MASS J01303563–4445411** was identified as an M9 dwarf by Reid et al. (2008b) and Faherty et al. (2009). Subsequently, Dhital et al. (2011) resolved this system as an M9+L6 pair with a 3.''2 separation. They note that the companion displays red colors for its spectral type, at  $1.7\sigma$  of the field L6 BDs, but the primary has normal NIR colors for its spectral type, which could be an indication that the companion has an unusually dusty atmosphere. They show that the optical spectrum of the primary does not display H $\alpha$  or Li, which indicates a minimal age of 250 Myr. Furthermore, a resolved NIR spectrum of the L6 companion does not display typical signs of youth such as a triangular H-band continuum. We thus conclude that this system must be a false positive in our analysis, despite its 90.6% Bayesian probability of being a member of

THA, since its age is not consistent with any YMG in the solar neighborhood.

**2MASS J02212859–6831400** has been identified as an M8 dwarf by Reid et al. (2008b), and Faherty et al. (2009) indicate that it is unusually red and for its spectral type and displays signs of low-gravity. Faherty et al. (2012) measured a trigonometric distance of  $39.4 \pm 5.6$  pc. This object was not considered as a strong candidate member of any YMG in Gagné et al. 2014c, but here we find it as a candidate member of ABDMG with a Bayesian probability of 40.8% and a contamination probability of  $< 0.1\%$ . This discrepancy is due to the **2MASS–AllWISE** proper motion, which is at  $2.2\sigma$  or  $5.0$  mas yr $^{-1}$  ( $\mu_\alpha \cos \delta$ ) and  $1.7\sigma$  ( $\mu_\delta$ ) or  $9.1$  mas yr $^{-1}$  of the proper motion used in the analysis of Gagné et al. (2014c) (which was measured by Faherty et al. 2012). We visually inspected the **2MASS** and **AllWISE** Atlas images and found that our cross-match between both catalogs is unambiguous, however it is possible that this candidate is a false positive in our analysis. A measurement of RV will be necessary to better constrain the membership of this object.

**2MASS J02401209–5305527** was reported as an M9.5 BD by Martín et al. (2010). They measured the equivalent width (EW) of the Na I doublet at 8170–8200 Å to be  $EW = 5.5 \pm 0.8$  Å. It is well known that low-gravity objects have a lower-than-normal Na I EW, however no classification scheme using this measurement extends to such a late spectral type. We note that this EW is low compared with other M9.5 BDs in their sample, for which Na I EWs range from 5.9 to 9.7 Å with an average and standard deviation of 7.3 and 1.3 Å respectively. However, it is higher than the Na I EW of low-gravity field BDs in their sample (**2MASS J04433761+0002051** with  $3.6 \pm 0.8$  Å and **2MASS J06085283–2753583** with  $5.0 \pm 0.7$  Å). NIR spectroscopy would be useful to clarify the age of **2MASS J02401209–5305527**.

**2MASS J03014892–5903021** and **2MASS J03252938–4312299** have both been identified as M9 dwarfs by Reid et al. (2008b). Martín et al. (2010) measured the equivalent width of their 8170–8200 Å Na I doublets and find  $4.5 \pm 0.8$  Å and  $5.1 \pm 0.8$  Å, respectively. They also revised the spectral type of **2MASS J03252938–4312299** to M8.5. In a similar way to **2MASS J02401209–5305527**, they have not flagged either objects as low-gravity, but both display the lowest Na I EW of all objects of their respective spectral types, except for Upper Scorpius candidates. NIR spectroscopy would be useful in clearly identifying potential signs of low-gravity in these objects.

**2MASS J03393521–3525440 (LP 944–20)** was identified as an M9 dwarf by Leggett et al. (2001). They used their lithium detection to constrain its age below 1 Gyr. Allers & Liu (2013) updated its spectral classification to an intermediate gravity L0 $\beta$ ; Reid et al. (2002) and Reiners & Basri (2009) measured a RV which Gagné et al. (2014c) combined to obtain  $9.3 \pm 1.7$  km s $^{-1}$ ; Dieterich et al. (2014) measured a trigonometric distance of  $6.41 \pm 0.04$  pc. Gagné et al. (2014c) used a previous parallax measurement from Tinney (1996);  $5.0 \pm 0.1$  pc) with the **BANYAN II** tool to derive a Bayesian probability of 17.5% that this is a member of ARG. However, Ribas (2003) indicated that it is a candidate member to the purported  $\sim 200$  Myr old Castor moving group (CAS; Barrado y Navascués 1998). They thus use an alternate Bayesian analysis similar to **BANYAN I** (Malo et al. 2013)



but including a SKM of CAS built from members reported by [Barrado y Navascués \(1998\)](#) and find a significantly larger Bayesian probability for CAS (99.7%). More recently, [Mamajek et al. \(2013\)](#) used updated distance and RV measurements of the original CAS members to demonstrate that they are too far apart in velocity space to be a part of a moving group of common origin. They thus argue that CAS likely a dynamical stream rather than a moving group, which is in line with the results of [Mamajek \(2012\)](#), [Monnier et al. \(2012\)](#) and [Zuckerman et al. \(2013\)](#). The difference in UVW space between [LP 944–20](#) and ARG is considerable ( $9.7 \text{ km s}^{-1}$ ) and comparable to its distance to Fomalhaut ( $13.5 \text{ km s}^{-1}$ ). We conclude that [LP 944–20](#) is likely a contaminant in our analysis, which could possibly be explained by the fact that our SKM model of field stars, derived from the Besançon galactic model ([Robin et al. 2014](#); [Robin et al. 2012](#)), does not explicitly include such dynamical streams that could act as an additional source of contamination.

[2MASS J05002100+0330501](#) was identified as an L4 dwarf by [Reid et al. \(2008b\)](#) and [Blake et al. \(2010\)](#) measured a RV of  $15.9 \pm 0.2 \text{ km s}^{-1}$ , from which we obtain a 62.8% membership probability associated with ABDMG. However, [Reid et al. \(2008b\)](#) specified that this object displays no notable peculiarities and would be a good spectral standard. While NIR spectroscopy could unambiguously rule out low-gravity, it is likely that this object is a field contaminant in our analysis.

[2MASS J05012406–0010452](#) has been identified by [Reid et al. \(2008b\)](#) as an L4 BD with signs of low-gravity in its optical spectrum. [Cruz et al. \(2009\)](#) updated its classification to L4 $\gamma$  using its optical spectrum, and [Allers & Liu \(2013\)](#) classified it as L3 $\gamma$  using NIR spectroscopy. [Faherty et al. \(2012\)](#) measured a trigonometric distance of  $13.1 \pm 0.8 \text{ pc}$ . [Gagné et al. 2014c](#) considered this object and found no obvious candidacy to any YMG considered here. However, we find that it has a 64.7% Bayesian probability of being a member of COL, associated with a 2.3% contamination probability. The discrepancy between this result and that of [Gagné et al. 2014c](#) is due to the  $\mu_\delta$  proper motion measurement from [2MASS–AllWISE](#), which is at  $2.8\sigma$  of the value they used (which was measured by [Faherty et al. 2012](#)). We visually inspected the [2MASS](#) and [AllWISE](#) Atlas images and found that our cross-match between both catalogs is unambiguous. Much like the case of [2MASS J02212859–6831400](#), a RV measurement will be needed to better constrain the membership of this object, but it is plausible that this object is a false-positive in our analysis.

[2MASS J10584787–1548172 \(DENIS–P J1058.7–1548\)](#) has been identified as an L3 dwarf by [Geballe et al. \(2002\)](#) and [Dahn et al. \(2002\)](#) measured a trigonometric distance of  $17.3 \pm 0.3 \text{ pc}$ , from which we obtain a 93.1% membership probability to ARG. [Reid et al. \(2008b\)](#) measured H $\alpha$  emission in its optical spectrum, but reported no further peculiarities. [Schneider et al. \(2014\)](#) subsequently measured the gravity-sensitive H $_2(K)$  in its NIR spectrum and obtain a value of 1.021, which is consistent with a field L3 dwarf. It is thus likely that this object is a field contaminant in our analysis.

[2MASS J12474428–3816464](#) has been identified by [Gagné et al. \(2014a\)](#) as a low-gravity M9 $\gamma$  candidate member of TWA, as part of the initial follow-up of the [BASS](#) survey. They note that its kinematics are discrepant with TWA albeit its low probability of being a field contaminant: its kinematics would match with TWA if it was placed further away, however this would make it over-luminous compared to young BDs

of the same spectral type and age. It could be expected that this is a contaminant from the Lower-Centaurus-Crux region (LCC;  $\sim 10$ – $20 \text{ Myr}$ ; [de Zeeuw et al. 1999](#)) of the Scorpius-Centaurus complex, but its distance ( $\sim 120 \text{ pc}$ ) would also make it over-luminous. It is possible that this object could be an unresolved binary and located further away, between TWA and LCC: this is reminiscent of [TWA 29](#) and [TWA 31](#), and might strengthen the proposition of [Song et al. \(2003\)](#); see also [Schneider et al. 2012a](#)) that TWA could actually be part of the LCC.

[2MASS J14252798–3650229](#) has been identified as an L5 BD by [Faherty et al. \(2009\)](#). Including RV and trigonometric distance measurements from [Blake et al. \(2010\)](#) and [Riedel et al. \(2014\)](#) respectively, we find a 99.6% probability that this object is a member of ABDMG, with 0.1% contamination probability. Only signs of youth need to be confirmed before we can consider this object as a new bona fide member of ABDMG, however we note that its has NIR colors  $J - K_s = 1.94$ , hence  $1\sigma$  redder than field L5 dwarfs, which could be an indication of youth.

[2MASS J17571539+7042011 \(LP 44–162\)](#) has been identified as an M7.5 dwarf by [Gizis et al. \(2000\)](#). [Tanner et al. 2010](#) and [Terrien et al. 2012](#) measured its radial velocity, which we combine in an error-weighted mean to obtain  $-12.4 \pm 0.6 \text{ km s}^{-1}$ . [Lépine et al. \(2009\)](#) measured a trigonometric distance of  $19.1 \pm 0.4 \text{ pc}$  and report that it is significantly over-luminous compared to dwarfs of the same colors, and propose that it might be an unresolved multiple. We find a Bayesian probability of 91.0% that this is a member of ARG. However, [Deshpande et al. \(2012\)](#) obtained high-resolution NIR spectroscopy and report pseudo-equivalent widths of K I lines in the  $J$  band which are consistent with M7.5 field dwarfs (e.g. see [Allers & Liu 2013](#)). It is thus plausible that this object is a false positive in our analysis, despite its high probability.

[SIMP J21543454–1055308](#) has been independently discovered in the *SIMP* survey for field BDs ([Artigau et al. 2009](#); [J. Robert et al., in preparation](#)). A NIR spectroscopic follow-up revealed that this object is a low-gravity L4 $\beta$  BD with an estimated mass of  $10 \pm 0.5 M_{\text{Jup}}$ , well into the planetary regime, if it is a member of ARG as suspected ([Gagné et al. 2014b](#)).

[2MASS J23225384+7847386](#) has been identified as an M5 proper motion companion to [V 368 Cep](#) and [LSPM J2322+7847](#) by [Makarov et al. \(2007\)](#). Using the X-ray luminosity of [V 368 Cep](#) as well as an isochrone analysis on all three components, they estimated an age of  $\sim 50 \text{ Myr}$  for the system. Using the RV measurement from [Kharchenko et al. \(2007\)](#), and combined trigonometric distances measurements from [Kharchenko et al. \(2007\)](#) and [Dittmann et al. \(2014\)](#), we find that this object has a 29.7% probability of being a member of CAR, with a contamination probability of 1.0%. The estimated age of this system is consistent with that of CAR, which makes it a compelling candidate member, even if its Bayesian probability is somewhat low. This low probability is a consequence of its galactic position  $XYZ = (-8.7 \pm 2.5, 16.1 \pm 4.6, 5.5 \pm 1.6) \text{ pc}$ , at  $2.5\sigma$  of our spatial model for CAR. We note however that its kinematics are a very good match to CAR with  $UVW = (-10.1 \pm 5.2, -23.5 \pm 2.9, -6.3 \pm 1.0)$ , at only  $0.5\sigma$  of our kinematic model. This could be an indication that CAR is in fact spatially larger than our present model, which would not be surprising since it was built from the only 7 currently known bona fide members. We

thus suggest that **2MASS J23225384+7847386** is probably a member in CAR, and that we might be currently missing more objects like this one as a result of our spatial and kinematic model for this association being too narrowly confined. Finding additional objects like this one will be needed to better constrain the SKM of CAR. Montes et al. (2001) suggested that **V 368 Cep** is a member of the Pleiades moving group (PMG; also called the Local Association), however we find that its kinematics are much more consistent with those of CAR, at only  $1.5 \text{ km s}^{-1}$  of our dynamical model, compared to a difference of  $5.5 \text{ km s}^{-1}$  with the kinematics of the PMG (Montes et al. 2001). Famaey et al. (2005) demonstrated that the PMG is likely a dynamical stream with a large spread in age rather than a coeval moving group, hence the age constraint acts as a further indication that a membership to CAR is more likely.

### 5. RECOVERY OF KNOWN CANDIDATES AND MEMBERS OF YOUNG MOVING GROUPS

In this Section, we assess the fraction of known  $\geq M5$  candidate members of YMGs that are recovered in the **BASS** and **LP-BASS** catalogs. We identified a total of 98 candidate members of the YMGs considered here in the literature (Schlieder

et al. 2012b; Shkolnik et al. 2012; Malo et al. 2013; Rodriguez et al. 2013; Gagné et al. 2014c; Kraus et al. 2014 and references therein). We do not include low-probability candidates from Gagné et al. (2014c) here, since they have a contamination probability of  $> 50\%$  by definition, which ensures that they are not listed in the **BASS** catalog. We find that a total of 55/98 of all these candidates are recovered in **BASS** (see Table 3), whereas 8 others are recovered in **LP-BASS** (see the Appendix), hence making up for 64% of currently known candidate members. All 35 candidates not recovered here are listed in Table 4, along with a list of the filters which caused them to be rejected. We note that 17 of those 36 candidates were missed only because they were cut from our input sample because of quality filters (i.e. low galactic latitude, low proper motion, large number of **2MASS** neighbors, poor **2MASS** or **AllWISE** photometric quality or NIR colors too blue), whereas 18 were missed at least because of a low Bayesian probability, high contamination probability or position in a CMD diagram derived from its statistical distance. Considering only the known candidate members that were part of our input search sample, the **BASS** and **LP-BASS** catalogs thus recover 68% of them.

TABLE 3  
CANDIDATES WITH ADDITIONAL INFORMATION IN THE LITERATURE.

<b>2MASS</b> Name	Measured SpT <sup>a</sup>	Signs of Youth <sup>b</sup>	RV ( $\text{km s}^{-1}$ )	Trig. Dist. (pc)	Multipli- city <sup>c</sup>	Known Membership	Updated Membership	Updated Prob. (%)
00011217+1535355	L4: <sup>51</sup>	...	...	...	...	...	ABDMG	77.8
00040288-6410358	L1 $\gamma$ <sup>49</sup>	OR <sup>49</sup>	...	...	...	THA <sup>49,31</sup>	THA	$> 99.9$
00065794-6436542	M9: <sup>82</sup>	OH <sup>72</sup>	...	...	...	THA <sup>31</sup>	THA	$> 99.9$
00160844-0043021	L5.5 <sup>51</sup>	...	...	...	...	...	BPMG	19.1
00192626+4614078	M8 <sup>94</sup>	LH <sup>83,94</sup>	$-19.5 \pm 3.0^{83}$	...	...	ABDMG <sup>92,31</sup>	ABDMG	92.1
00212774-6351081	M5.5 <sup>50</sup>	...	...	...	...	...	THA	99.8
00235732-5531435	M4.1 <sup>53</sup>	...	$5.3 \pm 0.7^{53}$	...	...	THA <sup>53</sup>	THA	99.8
00325584-4405058	L0 $\gamma$ <sup>16,71</sup>	OITRH <sup>16,71</sup>	...	$26.4 \pm 3.3^{28}$	...	BPMG <sup>31</sup>	BPMG	97.7
00354313+0233137	M5+M6 <sup>55</sup>	...	...	...	AB <sup>55</sup>	...	ABDMG	88.4
00374306-5846229	L0 $\gamma$ <sup>82,16</sup>	OR <sup>16</sup>	...	...	...	THA <sup>31</sup>	THA	99.9
00390342+1330170	...	XN <sup>92</sup>	...	...	...	ABDMG <sup>92</sup>	BPMG	91.9
00413538-5621127	M6.5+M9 <sup>94</sup>	VHLA <sup>90</sup>	$2.8 \pm 1.9^{83,34,31}$	...	AB <sup>94</sup>	THA <sup>31</sup>	THA	$> 99.9$
00452143+1634446	L2 $\beta$ <sup>82,16</sup>	OITRH <sup>16</sup>	$3.3 \pm 0.2^4$	$17.5 \pm 0.6^{14}$	...	ARG <sup>31</sup>	ARG	98.0
00464841+0715177	M9 <sup>82,118</sup>	...	...	...	...	...	BPMG	77.0
00514081-5913320	M4.4 <sup>53</sup>	...	$6.3 \pm 1.3^{53}$	...	...	THA <sup>53</sup>	THA	99.9
01033203+1935361	L6 $\beta$ <sup>28,119</sup>	OITR <sup>27,28</sup>	...	$21.3 \pm 3.4^{28}$	...	ARG <sup>31</sup>	ARG	78.2
01033563-5515561	M5.5 <sup>19,53</sup>	OHU <sup>19,89</sup>	$5.2 \pm 1.6^{68,53}$	$47.2 \pm 3.1^{89}$	AB <sup>19</sup>	THA;CAR <sup>19,89</sup>	THA	99.9
01134031-5939346	M5.0 <sup>53</sup>	...	$11.9 \pm 6.7^{53}$	...	...	THA <sup>53</sup>	THA	99.7
01174748-3403258	L1 $\beta$ <sup>14,2</sup>	TRM <sup>7,112,2</sup>	...	...	...	THA <sup>31</sup>	THA	99.6
01180670-6258591	M5.1 <sup>53</sup>	L <sup>53</sup>	$9.3 \pm 1.3^{53}$	...	...	THA <sup>53</sup>	THA	$> 99.9$
01231125-6921379	M8 <sup>94</sup>	UL <sup>83</sup>	$10.9 \pm 3.0^{83}$	$42.2 \pm 4.8^{87}$	...	THA <sup>31d</sup>	THA	$> 99.9$
01243060-3355014	M4.5 <sup>89</sup>	OU <sup>89</sup>	$18.3 \pm 0.5^{100}$	$25.3 \pm 0.8^{100,89}$	C <sup>106</sup>	ABDMG <sup>88,100d</sup>	ABDMG	$> 99.9$
01294256-0823580	M5 <sup>81</sup>	...	...	...	...	...	BPMG	66.2
01344601-5707564	M4.9 <sup>53</sup>	L <sup>53</sup>	$11.1 \pm 6.3^{53}$	...	...	THA <sup>53</sup>	THA	99.8
01372781-4558261	M5.0 <sup>53</sup>	L <sup>53</sup>	$13.5 \pm 1.4^{53}$	...	...	THA <sup>53</sup>	THA	97.8
01415823-4633574	L0 $\gamma$ <sup>120,16</sup>	OITRHM <sup>120,16</sup>	$12.0 \pm 15.0^{53}$	...	...	THA <sup>31</sup>	THA	99.5
01443191-4604318	M5.5 <sup>76</sup>	...	...	...	...	...	THA	99.1
01504543-5716488	M5.5 <sup>53</sup>	L <sup>53</sup>	$9.3 \pm 1.7^{53}$	...	...	THA <sup>53</sup>	THA	$> 99.9$
01531463-6744181	L2: <sup>82</sup>	...	...	...	...	...	THA	99.9
01532494-6833226	M5.1 <sup>90,53</sup>	N <sup>90</sup>	$9.8 \pm 1.4^{53}$	...	...	THA <sup>90,53</sup>	THA	$> 99.9$
02153328-5627175	M5.4 <sup>90,53</sup>	LN <sup>53</sup>	$11.3 \pm 5.7^{53}$	...	...	THA <sup>90,53</sup>	THA	99.8
02180960-6657524	M4.5 <sup>53</sup>	L <sup>53</sup>	$11.0 \pm 1.2^{53}$	...	...	THA <sup>53</sup>	THA	$> 99.9$
02192210-3925225	M4.9 <sup>53</sup>	L <sup>53</sup>	$10.6 \pm 0.7^{53}$	...	...	THA <sup>53</sup>	THA	$> 99.9$
02212859-6831400	M8: <sup>82</sup>	OR <sup>27</sup>	...	$39.4 \pm 5.6^{28}$	...	...	ABDMG	40.8
02215494-5412054	M8 $\beta$ <sup>82,27</sup>	OR <sup>16</sup>	...	...	...	THA <sup>31</sup>	THA	99.8
02235464-5815067	L0 $\gamma$ <sup>82,27</sup>	OR <sup>82</sup>	...	...	...	THA <sup>31</sup>	THA	$> 99.9$
02251947-5837295	M9 <sup>82,27</sup>	O <sup>82</sup>	...	...	...	THA <sup>31</sup>	THA	99.9
02294869-6906044	M4.6 <sup>53</sup>	L <sup>53</sup>	$13.0 \pm 1.2^{53}$	...	...	THA <sup>53</sup>	THA	$> 99.9$
02321934-5746117	M4.4 <sup>90,53</sup>	...	$11.2 \pm 0.7^{53}$	...	...	THA <sup>53</sup>	THA	$> 99.9$

TABLE 3 — *Continued*

2MASS Name	Measured SpT <sup>a</sup>	Signs of Youth <sup>b</sup>	RV (km s <sup>-1</sup> )	Trig. Dist. (pc)	Multipli- city <sup>c</sup>	Known Membership	Updated Membership	Updated Prob. (%)
02340093-6442068	L0 $\gamma$ <sup>29</sup>	OR <sup>29</sup>	...	...	...	THA <sup>49,31</sup>	THA	99.8
02401209-5305527	M9.5 <sup>72</sup>	...	...	...	...	...	THA	99.9
02411151-0326587	L0 $\gamma$ <sup>64,15,16,48</sup>	OTR <sup>15,16,2</sup>	...	46.7 $\pm$ 5.7 <sup>114</sup>	...	THA <sup>31</sup>	THA	98.3
02435103-5432194	M9 <sup>82</sup>	...	...	...	...	...	THA	99.9
02501167-0151295	...	...	...	33.1 $\pm$ 4.9 <sup>107</sup>	...	...	BPMG	88.3
02523550-7831183	M4.4 <sup>53</sup>	...	12.8 $\pm$ 1.3 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	98.6
02534448-7959133	M5.5 <sup>76</sup>	H <sup>56</sup>	...	...	...	...	BPMG	50.1
03014892-5903021	M9 <sup>82,72</sup>	...	...	...	...	...	THA	99.9
03032042-7312300	L2 $\gamma$ <sup>49</sup>	OR <sup>49</sup>	...	...	...	THA <sup>49,31</sup>	THA	78.2
03050556-5317182	M5.4 <sup>90,53</sup>	N <sup>90</sup>	12.1 $\pm$ 2.2 <sup>53</sup>	...	...	THA <sup>90,53</sup>	THA	99.9
03093877-3014352	M4.7 <sup>53</sup>	L <sup>53</sup>	12.5 $\pm$ 2.3 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	99.9
03114544-4719501	M4.3 <sup>90,53</sup>	N <sup>90</sup>	11.3 $\pm$ 0.5 <sup>53</sup>	...	...	THA <sup>90,53</sup>	THA	> 99.9
03152363-5342539	M5.2 <sup>90</sup>	N <sup>90</sup>	...	...	...	THA <sup>90</sup>	THA	99.9
03164512-2848521	L0.1 <sup>4</sup>	...	...	...	...	...	ABDMG	77.2
03231002-4631237	L0 $\gamma$ <sup>82,27</sup>	ORL <sup>16</sup>	...	...	...	THA <sup>31</sup>	THA	99.7
03252938-4312299	M9 <sup>82,72</sup>	...	...	...	...	...	THA	78.9
03264225-2102057	L4 <sup>15</sup>	ORL <sup>15</sup>	...	...	...	ABDMG <sup>31</sup>	ABDMG	98.9
03363144-2619578	M5.7 <sup>90</sup>	N <sup>90</sup>	...	43.5 $\pm$ 3.8 <sup>89</sup>	...	THA <sup>90</sup>	THA	99.9
03390160-2434059	M5.9 <sup>90</sup>	N	...	...	...	COL <sup>90</sup>	COL	77.8
03393521-3525440	L0 $\beta$ <sup>2,44,27</sup>	TLM <sup>27,112,2</sup>	9.3 $\pm$ 1.7 <sup>83,77</sup>	6.41 $\pm$ 0.04 <sup>22</sup>	...	CAS <sup>86,31</sup>	ARG	87.6
03421621-6817321	L2.1 <sup>5</sup>	R <sup>27</sup>	...	...	...	THA <sup>31</sup>	THA	99.7
03550477-1032415	M8.5 <sup>14,27</sup>	...	...	...	...	...	BPMG	39.5
03552337+1133437	L5 $\gamma$ <sup>82,27</sup>	OITRL <sup>16</sup>	11.9 $\pm$ 0.2 <sup>4</sup>	9.1 $\pm$ 0.1 <sup>61,28</sup>	AB <sup>3</sup>	ABDMG <sup>61,31d</sup>	ABDMG	99.7
03572695-4417305	M9 $\beta$ +L1.5 $\beta$ <sup>60</sup>	OR <sup>16</sup>	...	...	AB <sup>60</sup>	THA <sup>31</sup>	THA	99.9
03582255-4116060	L5 <sup>82,27</sup>	...	...	...	...	...	BPMG	36.8
04174743-2129191	M8 <sup>15,27</sup>	...	...	...	...	...	THA	57.7
04210718-6306022	L5 $\gamma$ <sup>82,27</sup>	OIRL <sup>15</sup>	...	...	...	ARG:BPMG <sup>31</sup>	ARG	97.7
04362788-4114465	M8 $\gamma$ <sup>15,2</sup>	OITR <sup>15,2</sup>	...	...	...	COL <sup>31</sup>	COL	97.6
04433761+0002051	M9 $\gamma$ <sup>15,2</sup>	OITVRHL <sup>27,72,31,2</sup>	17.1 $\pm$ 3.0 <sup>83</sup>	...	...	BPMG <sup>31,92</sup>	BPMG	99.8
04532647-1751543	L3.1 <sup>4</sup>	...	...	...	...	...	COL	95.8
04533604-2835349	...	...	22.5 $\pm$ 6.7 <sup>52</sup>	...	...	...	COL	87.6
05002100+0330501	L3 $\gamma$ <sup>82,27</sup>	...	15.9 $\pm$ 0.2 <sup>4</sup>	...	...	...	ABDMG	62.8
05012406-0010452	L3 $\gamma$ <sup>82,16,2</sup>	OTRL <sup>27</sup>	...	14.7 $\pm$ 2.8 <sup>28,114</sup>	...	FIELD <sup>31</sup>	CAR	97.7
05120636-2949540	L4.1 <sup>4</sup>	R <sup>48</sup>	...	...	...	BPMG <sup>31</sup>	BPMG	33.8
05181131-3101529	M6.5 <sup>12</sup>	...	...	...	...	...	COL	93.7
05361998-1920396	L2 $\gamma$ <sup>29</sup>	OITR <sup>29,2</sup>	...	39.0 $\pm$ 14.0 <sup>28</sup>	...	COL <sup>31</sup>	COL	96.6
06022216+6336391	L1.8 <sup>2</sup>	...	...	...	...	...	ABDMG	26.1
06420559+4101599	L/Tp <sup>65</sup>	R <sup>65</sup>	...	...	...	ABDMG <sup>31</sup>	ABDMG	38.4
06524851-5741376	M8 $\beta$ <sup>82,27</sup>	OR <sup>82,27</sup>	...	32.0 $\pm$ 3.3 <sup>28</sup>	AB <sup>10</sup>	ABDMG <sup>31</sup>	CAR	87.9
08095903+4434216	L6 <sup>51,116</sup>	...	...	...	...	...	ARG	30.7
09455843-3253299	M4.5 <sup>85</sup>	X <sup>85</sup>	...	...	...	...	ARG	89.2
09532126-1014205	L0 <sup>15</sup>	...	...	...	...	...	CAR	63.7
10284580-2830374	M5 <sup>96</sup>	...	...	...	...	TWA <sup>96</sup>	TWA	96.3
10582800-1046304	M4 <sup>91</sup>	...	...	...	...	...	TWA	4.3
10584787-1548172	L3 <sup>36</sup>	...	...	17.3 $\pm$ 0.3 <sup>18</sup>	...	...	ARG	93.1
11020983-3430355	M8.5 $\gamma$ <sup>28,116</sup>	...	...	56.4 $\pm$ 1.6 <sup>104</sup>	...	TWA <sup>116</sup>	TWA	99.8
11393382-3040002	M4.7 <sup>96</sup>	...	...	...	...	TWA <sup>96</sup>	TWA	99.0
11395113-3159214	M8 $\gamma$ <sup>38,82,2</sup>	OITRM <sup>38,112</sup>	11.2 $\pm$ 2.0 <sup>69</sup>	28.5 $\pm$ 3.5 <sup>28</sup>	...	TWA <sup>38,69d</sup>	TWA	99.8
12073346-3932539	M8 <sup>48</sup>	ORL <sup>48,17,2</sup>	...	52.3 $\pm$ 1.1 <sup>24</sup>	Ab <sup>10</sup>	TWA <sup>38,69d</sup>	TWA	99.6
12074836-3900043	L1 $\gamma$ <sup>32</sup>	OITR <sup>32</sup>	...	...	...	TWA <sup>32</sup>	TWA	99.7
12474428-3816464	M9 $\gamma$ <sup>32</sup>	ITR <sup>32</sup>	...	...	...	TWA <sup>32</sup>	TWA	47.1
13262009-2729370	L5 <sup>38,82</sup>	...	...	...	...	...	ARG	23.3
14252798-3650229	L5 <sup>51,82</sup>	...	5.4 $\pm$ 0.3 <sup>4</sup>	11.6 $\pm$ 0.1 <sup>22</sup>	...	...	ABDMG	99.6
17571539+7042011	M7.5 <sup>37</sup>	U <sup>57</sup>	-12.4 $\pm$ 0.6 <sup>103,20</sup>	19.1 $\pm$ 0.4 <sup>57</sup>	...	...	ARG	91.0
19564700-7542270	L0 $\gamma$ <sup>15</sup>	OR <sup>90</sup>	...	...	...	THA <sup>31</sup>	THA	85.2
20004841-7523070	M9 <sup>94</sup>	OR <sup>90</sup>	11.8 $\pm$ 1.0 <sup>34</sup>	...	...	CAS:BPMG <sup>34,31</sup>	BPMG	98.2
20111744-2917584	M5.5 <sup>81</sup>	...	...	...	...	...	ARG	49.3
20224803-5645567	M5.5 <sup>12</sup>	...	...	...	...	...	THA	59.2
20291446-5456116	M4.3 <sup>53</sup>	...	-1.4 $\pm$ 1.2 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	71.4
20330186-4903105	...	...	...	16.3 $\pm$ 5.0 <sup>89</sup>	...	...	BPMG	99.1
20334670-3733443	M5 <sup>81</sup>	...	...	...	...	...	BPMG	80.0
20414283-3506442	L2.1 <sup>5</sup>	...	...	...	...	...	ABDMG	14.4
20423672-5425263	M4.0 <sup>53</sup>	...	-1.4 $\pm$ 1.7 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	94.8
21083826-4244540	M4.4 <sup>53</sup>	...	-4.9 $\pm$ 1.9 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	84.4
21265040-8140293	L3 $\gamma$ <sup>82</sup>	OR <sup>90</sup>	...	...	...	THA <sup>31</sup>	THA	85.1
21420580-3101162	L2 <sup>58,27,8</sup>	...	...	...	...	...	ABDMG	12.6
21490499-6413039	M4.5 <sup>85,53</sup>	X <sup>85</sup>	0.4 $\pm$ 5.1 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	99.7



TABLE 3 — *Continued*

<i>2MASS</i> Name	Measured SpT <sup>a</sup>	Signs of Youth <sup>b</sup>	RV (km s <sup>-1</sup> )	Trig. Dist. (pc)	Multipli- city <sup>c</sup>	Known Membership	Updated Membership	Updated Prob. (%)
21543454-1055308	L4 $\beta^{33}$	ITR <sup>33</sup>	...	...	...	ARG <sup>33</sup>	ARG	58.6
22060961-0723353	M5.5 <sup>78</sup>	...	...	...	...	...	ABDMG	82.1
22064498-4217208	L2 <sup>14</sup>	R <sup>14</sup>	...	...	...	ABDMG <sup>31</sup>	ABDMG	95.2
22244102-7724036	M4.2 <sup>53</sup>	...	8.5 $\pm$ 1.4 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	99.2
22400144+0532162	...	...	...	23.6 $\pm$ 2.7 <sup>23</sup>	...	...	BPMG	79.0
22443167+2043433	L6 $\gamma^{82,2}$	ITRLM <sup>90</sup>	...	...	...	ABDMG <sup>31</sup>	ABDMG	99.8
22444835-6650032	M4.8 <sup>53</sup>	L <sup>53</sup>	0.7 $\pm$ 1.7 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	99.7
22583200+1014589	...	...	...	23.1 $\pm$ 1.4 <sup>23</sup>	...	...	ABDMG	98.3
23130558-6127077	M4.5 <sup>53</sup>	L <sup>53</sup>	2.9 $\pm$ 2.3 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	99.8
23225240-6151114	M5 <sup>31</sup>	...	...	...	A <sup>31</sup>	THA <sup>31</sup>	THA	98.7
23225299-6151275	L2 $\gamma^{82}$	OR <sup>16</sup>	...	...	B <sup>31</sup>	THA <sup>31</sup>	THA	> 99.9
23225384+7847386	M5 <sup>66</sup>	UC <sup>66</sup>	-17.0 $\pm$ 1.3 <sup>46</sup>	19.1 $\pm$ 5.5 <sup>66,23</sup>	B <sup>66</sup>	Pleiades <sup>74</sup>	CAR	29.7
23255604-0259508	L3 <sup>8</sup>	...	...	...	...	...	ABDMG	29.8
23392527+3507165	L3.5 <sup>82,8</sup>	...	...	...	...	...	BPMG	10.6
23424333-6224564	M4.3 <sup>53</sup>	...	5.1 $\pm$ 4.6 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	99.6
23520507-1100435	M7 <sup>14,58,15</sup>	...	...	...	...	...	ABDMG	42.0

<sup>a</sup> The  $\beta$  and  $\gamma$  symbols stand for low-gravity and very low-gravity,  $p$  stands for peculiar, and a semi-colon indicates an uncertain spectral type.

<sup>b</sup> A capital letter means the object displays the associated sign of youth. O: lower-than normal equivalent width of atomic species in the optical spectrum, I: same but in the NIR spectrum, T: a triangular-shaped  $H$ -band continuum, V: high rotational velocity, X: X-ray emission, R: redder-than-normal colors for given spectral type, U: over luminous, H: H $\alpha$  emission, L: Li absorption, A: signs of accretion, M: signs of low gravity from atmospheric models fitting, N: bright NUV emission and C: Companion to a young star. A question mark following a flag indicates that the result is uncertain.

<sup>c</sup> AB: Unresolved binary, B or C: Resolved companion.

<sup>d</sup> Bona fide member.

References to the table :

(1) Allen et al. 2007; (2) Allers & Liu 2013; (3) Bernat et al. 2010; (4) Blake et al. 2010; (5) Bochanski et al. 2005; (6) Boyer et al. 2011; (7) Burgasser et al. 2008; (8) Burgasser et al. 2010; (9) Caballero 2007; (10) ?; (11) Costa et al. 2005; (12) ?; (13) Cruz & Reid 2002; (14) Cruz et al. 2003; (15) Cruz et al. 2007; (16) Cruz et al. 2009; (17) ?; (18) Dahn et al. 2002; (19) ?; (20) Terrien et al. 2012; (21) Dhital et al. 2011; (22) Dieterich et al. 2014; (23) Dittmann et al. 2014; (24) ?; (25) Dupuy & Liu 2012; (26) Finder Charts; (27) Faherty et al. 2009; (28) Faherty et al. 2012; (29) Faherty et al. 2013; (30) ?; (31) Gagné et al. 2014c; (32) Gagné et al. 2014a; (33) Gagné et al. 2014b; (34) Gálvez-Ortiz et al. 2010; (35) Gatewood & Coban 2009; (36) Geballe et al. 2002; (37) Gizis et al. 2000; (38) Gizis 2002; (39) Gould & Chanamé 2004; (40) ?; (41) Gizis et al. 1997; (42) ?; (43) Janson et al. 2012; (44) Jenkins et al. 2009; (45) Kendall et al. 2007; (46) Kharchenko et al. 2007; (47) Khovritchev et al. 2013; (48) Kirkpatrick et al. 2008; (49) Kirkpatrick et al. 2010; (50) Kirkpatrick et al. 2011; (51) Knapp et al. 2004; (52) 201 2013; (53) Kraus et al. 2014; (54) ?; (55) Law et al. 2008; (56) Lee et al. 2010; (57) Lépine & Simon 2009; (58) Liebert & Gizis 2006; (59) Liu et al. 2008; (60) Liu et al. 2010; (61) Liu et al. 2013a; (62) Liu et al. 2013b; (63) Loofer et al. 2007; (64) Luhman et al. 2009; (65) Mace et al. 2013; (66) Makarov 2007; (67) Malo et al. 2013; (68) Malo et al. 2014a; (69) Mamajek 2005; (70) Mann et al. 2013; (71) Marocco et al. 2013; (72) ?; (73) Mason et al. 2001; (74) Montes et al. 2001; (75) Newton et al. 2014; (76) ?; (77) Reid et al. 2002; (78) Reid et al. 2003; (79) Reid et al. 2004; (80) Reid et al. 2006; (81) Reid et al. 2007; (82) Reid et al. 2008a; (83) Reiners & Basri 2009; (84) Reylé et al. 2006; (85) Riaz et al. 2006; (86) ?; (87) A. R. Riedel et al., in preparation; (88) Riedel 2012; (89) Riedel et al. 2014; (90) Rodriguez et al. 2013; (91) Rojas-Ayala et al. 2012; (92) Schlieder et al. 2012a; (93) Schlieder et al. 2012b; (94) Schmidt et al. 2007; (95) Schmidt et al. 2010; (96) Schneider et al. 2012b; (97) Schneider et al. 2014; (98) ?; (99) Shkolnik et al. 2009; (100) Shkolnik et al. 2012; (101) Zwitter et al. 2008; (102) Subasavage et al. 2005; (103) Tanner et al. 2010; (104) ?; (105) ?; (106) ?; (107) Tinney 1996; (108) Tinney 1996; (109) van Leeuwen 2007; (110) Vrba et al. 2004; (111) West et al. 2008; (112) ?; (113) Zacharias et al. 2012; (114) ?; (115) Nidever et al. 2002; (116) ?; (117) Chiu et al. 2006; (118) Wilson et al. 2003; (119) Kirkpatrick et al. 2000; (120) Kirkpatrick et al. 2006.

TABLE 4  
KNOWN YMG CANDIDATE MEMBERS NOT RECOVERED IN *BASS*.

<i>2MASS</i> Designation	Measured SpT <sup>a</sup>	Known Candidacy	Reason for Rejection <sup>b</sup>
00332386-1521309	L4 $\beta$	ARG <sup>31</sup>	$HW2_{CMD}$
00470038+6803543	L7p	ABDMG <sup>31</sup>	$b, 2M_{\#}$
01112542+1526214	M5+M6	$\beta$ PMG <sup>67</sup>	$W1_{SAT}$
01291221+3517580	L4	ARG <sup>31</sup>	$HW2_{CMD}$
01424687-5126469	M6.5	COL <sup>90</sup>	$J-H, 2M_{PH}, \sigma\mu, \mu, P, C$
02535980+3206373	M7p	$\beta$ PMG <sup>31</sup>	$HW2_{CMD}, P$
03214475-3309494	M5.8	COL <sup>90</sup>	$V-J, 2M_{PH}, P, C$
03244305-2733230	M5.5	COL <sup>90</sup>	$K_S-W1, \mu, P, C$
03350208+2342356	M8.5	$\beta$ PMG <sup>100</sup>	$W1_{SAT}, W2_{SAT}, C$
04062677-3812102	L0 $\gamma$	COL <sup>31</sup>	$P, C$
05184616-2756457	L1 $\gamma$	COL <sup>31</sup>	$\mu$
06195260-2903592	M6	COL <sup>31</sup>	$\mu$
06322402-5010349	L3	ABDMG <sup>31</sup>	$HW2_{CMD}, \sigma\mu, C$
07285117-3015527	M5	ABDMG <sup>100</sup>	$b, W1_{SAT}, 2M_{\#}$
09445422-1220544	M5	ARG <sup>67</sup>	$W1-W2, W1_{SAT}$

TABLE 4 — *Continued*

2MASS Designation	Measured SpT <sup>a</sup>	Known Candidacy	Reason for Rejection <sup>b</sup>
10042066+5022596	L3 $\beta$	ABDMG <sup>31</sup>	$W1_{SAT}$ , $P$ , $C$
10172689-5354265	M5	$\beta$ PMG <sup>105</sup>	$b$ , $J-H$ , $W1_{SAT}$ , $2M_{\#}$
11321831-3019518	M5	TWA <sup>67</sup>	$H-K_S$ , $K_S-W1$
11324116-2652090	M5	TWA <sup>69</sup>	$H-K_S$ , $K_S-W1$ , $2M_{CC}$ , $W1_{SAT}$ , $W_{CC}$
12242443-5339088	M5	$\beta$ PMG <sup>67</sup>	$b$ , $K_S-W1$ , $HW2_{CMD}$ , $2M_{\#}$
12451416-4429077	M9.5p	TWA <sup>31</sup>	$2M_{\#}$
13142039+1320011	M7	ABDMG <sup>93</sup>	$P$
16002647-2456424	M7.5p	ABDMG <sup>31</sup>	$JK_{CMD}$ , $HW2_{CMD}$ , $USco$ , $2M_{\#}$ , $P$ , $C$
16471580+5632057	L9p	ARG <sup>31</sup>	$P$ , $C$
17410280-4642218	L7p	$\beta$ PMG;ABDMG <sup>97</sup>	$b$ , $2M_{CC}$ , $2M_{\#}$
18450097-1409053	M5	ARG <sup>67</sup>	$b$ , $W1-W2$ , $2M_{CC}$ , $2M_{PROX}$ , $W1_{SAT}$ , $W2_{SAT}$ , $2M_{\#}$ , $P$
21011544+1756586	L7.5	ABDMG <sup>31</sup>	$2M_{PH}$ , $2M_{CC}$ , $2M_{\#}$
21103096-2710513	M5	$\beta$ PMG <sup>67</sup>	$WISE$
21140802-2251358	L7	$\beta$ PMG <sup>62</sup>	$2M_{PH}$
21354554-4218343	M5.2	THA <sup>53</sup>	$B-V$ , $P$ , $C$
21374019+0137137	M5	$\beta$ PMG <sup>93</sup>	$H-K_S$ , $W1_{SAT}$
21481633+4003594	L6	ARG <sup>31</sup>	$b$ , $2M_{\#}$
22081363+2921215	L3 $\gamma$	$\beta$ PMG <sup>31</sup>	$P$ , $C$
23204705-6723209	M5	THA <sup>67</sup>	$V-J$ , $2M_{PH}$ , $2M_{CC}$ , $\sigma\mu$
23512200+3010540	L5.5	ARG <sup>31</sup>	$B-J$ , $\chi^2_{W1}$ , $2M_{BL}$ , $HW2_{CMD}$

<sup>a</sup> Measured in the NIR unless symbol otherwise specified.

<sup>b</sup> This column contains codes corresponding to the filters that rejected an object from the **BASS** catalog; (1) *WISE* – No entry in the *WISE* and *AllWISE* catalogs, (2) *b* – Absolute Galactic latitude is too low, (3) *B-V* color is too blue, (4) *B-J* color is too blue, (5) *V-J* color is too blue, (6) *J-H* color is too blue, (7) *H-K<sub>S</sub>* color is too blue, (8) *K<sub>S</sub>-W1* color is too blue, (9) *W1-W2* color is too blue, (10)  $\chi^2_{W1}$  – the reduced  $\chi^2$  from the adjusted profile in the *W1* band is too large, (11)  $2M_{PH}$  – **2MASS** photometric quality is too low, (12)  $2M_{BL}$  – A blend flag is suspicious in **2MASS**, (13)  $2M_{CC}$  – A contamination flag is suspicious in **2MASS**, (14)  $2M_{PROX}$  – A close-by **2MASS** source is unresolved in *AllWISE*, (15)  $W1_{SAT} - W1$  magnitude is saturated, (16)  $W2_{SAT} - W2$  magnitude is saturated,  $W_{CC}$  – A contamination flag is suspicious in *AllWISE*, (17)  $JK_{CMD}$  – The object falls to the left of the  $M_{W1}$  versus  $J-K_S$  field sequence using its statistical distance, (18)  $HW2_{CMD}$  – The object falls to the left of the  $M_{W1}$  versus  $H-W2$  field sequence using its statistical distance, (19) *USco* – The object is too close to Upper Scorpius, (20)  $2M_{\#}$  – The object has too many immediate neighbours in **2MASS**, (21)  $\sigma\mu$  – the **2MASS-AllWISE** proper motion is not precise enough, (22)  $\mu$  – The proper motion is too low, (23)  $P$  – The Bayesian probability is too low, (24)  $C$  – The contamination probability is too high. See Sections 2–3 for detailed descriptions of these respective filters.

References to this table are identical to those of Table 3.

## 6. THE UPDATED **BASS** SAMPLE

We present in Table 5 a complete list of the **BASS** sample, which contains only objects respecting all criteria mentioned in Sections 2–3 after taking account of all information available in the literature. We list in this table all the contamination probability of all objects, obtained from the Monte Carlo analysis described in Section 3, as well as statistical estimates for their distance and RV. We refer to this list as the **BASS** sample for the remainder of this work. We used the individual contamination probability of all candidate members to estimate an average contamination fraction from field stars of 2.4% and 29.5% for the high probability and modest probability samples, respectively. These estimates of contamination do not take account of possible cross-contamination between the YMGs considered here, or other, older nearby associations not considered, e.g. Carina-Near ( $\sim 200$  Myr; Zucker-

man et al. 2006), the Ursa Major moving ( $\sim 500$  Myr; King et al. 2003) and the Hercules-Lyra association ( $\sim 250$  Myr; Eisenbeiss et al. 2013). Another way to assess a minimal contamination rate is to count the fraction of candidates with RV, distance or spectra in the literature which were rejected from these measurements. This estimate yields a larger contamination rate of 12.6% (11/87) for the high probability candidates. Small number statistics prevent an accurate estimation for the low-probability candidates: only 37 had such measurements in the literature, from which 4 were rejected. We rather choose to scale the observed 12.6% contamination fraction of the high-probability sample with the ratio of predicted contamination fractions of both samples to estimate a more reliable expected contamination fraction of  $\sim 71\%$  for the modest probability **BASS** sample.

In Figures 14–20, we compare proper motions and sky positions of the **BASS** sample with currently known bona fide members of YMGs; it can be seen that, as expected, trajectories of candidates in the **BASS** sample projected on the celestial sphere are consistent with known bona fide members. In Figure 3, we use the statistical distances from **BANYAN II** to display the position of candidates of the **BASS** sample in two color-magnitude diagrams: absolute *W1* as a function of *H-W2*, and absolute *W1* as a function of *J-K<sub>S</sub>*. These two CMDs are used as observable in the **BANYAN II** tool as they are useful to distinguish young  $> M5$  dwarfs from their field counterparts. In Figures 21–27, we compare the statistical predictions for galactic positions (*XYZ*) and space velocities (*UVW*) of all **BASS** candidates with those of currently known bona fide members of YMGs, as well as the  $1.557\sigma$  contours of the SKM ellipsoids used in **BANYAN II**. We use  $1.557\sigma$  as the 3-dimensional analog to  $1\sigma$  in one dimension in the sense that it encompasses 68% of objects drawn from a gaussian random PDF.

### 6.1. Mass Estimates

We used the YMG age and statistical distance associated to the most probable hypothesis from **BANYAN II** and the **AMES-Cond** isochrones (Baraffe et al. 2003) in combination with the CIFIST2011 BT-SETTL atmosphere models (Allard

et al. 2013; Rajpurohit et al. 2013) to estimate the mass of all candidates presented here. A uniform distribution spanning the age range of each YMG was used to compare their absolute  $J$ ,  $H$ ,  $K_s$ ,  $W1$  and  $W2$  magnitudes with model isochrones in a maximum likelihood analysis. Mass estimates are listed in Table 5. The **BASS** sample comprises 79 new candidate young BDs and 22 candidate planetary-mass objects.

TABLE 5  
THE COMPLETE **BASS** CATALOG.

<b>2MASS</b> Designation	Spectral Type <sup>a</sup>	Probable Membership	Bayesian Prob. (%)	Contamination Prob. (%)	Estimated Mass Range ( $M_{\text{Jup}}$ )	Statistical Distance (pc)	Statistical RV (km s <sup>-1</sup> )
Candidates with a High Probability							
00011217+1535355	L4:	ABDMG	77.8	1.8	$17.5^{+0.8}_{-1.1}$	$27.3 \pm 1.6$	$-6.5 \pm 2.0$
00040288-6410358	L1 $\gamma$	THA	> 99.9	< 0.1	$12.8 \pm 0.3$	$45.0 \pm 2.4$	$6.5 \pm 2.5$
00041589-8747254	(M5.7)	THA	55.4	< 0.1	$60.9^{+8.8}_{-7.1}$	$51.8 \pm 3.6$	$11.3 \pm 2.2$
00065794-6436542	M9:	THA	> 99.9	< 0.1	$20.5^{+1.1}_{-13.9}$	$41.4 \pm 2.4$	$6.2 \pm 2.4$
00111532-3756553	(M5.7)	THA	80.2	< 0.1	$60.6^{+8.6}_{-6.7}$	$38.2^{+2.0}_{-2.4}$	$1.5 \pm 2.2$
00182834-6703130	(M9.6)	THA	99.8	< 0.1	$13.3 \pm 0.3$	$43.8^{+2.8}_{-2.4}$	$6.9 \pm 2.5$
00191296-6226005	(M9.7)	THA	99.5	< 0.1	$13.3^{+0.3}_{-0.4}$	$46.6^{+2.4}_{-2.8}$	$6.7 \pm 2.5$
00192626+4614078	M8	ABDMG	92.1	4.1	$87.1^{+8.5}_{-8.6}$	$37.8 \pm 3.2$	$-19.5 \pm 3.0$
00212774-6351081	M5.5	THA	99.8	< 0.1	$158.3^{+19.9}_{-18.5}$	$44.2^{+2.8}_{-2.4}$	$6.8 \pm 2.4$
00235732-5531435	M4.1	THA	99.8	< 0.1	$133.1^{+17.4}_{-14.6}$	$41.4 \pm 2.4$	$5.3 \pm 0.7$
Candidates with a Modest Probability							
00160844-0043021	L5.5	BPMG	19.1	36.1	$9.6 \pm 0.3$	$30.9^{+2.8}_{-3.2}$	$3.3 \pm 1.8$
00274534-0806046	(M5.3)	BPMG	45.6	35.1	$66.9 \pm 4.2$	$32.1 \pm 2.8$	$4.4 \pm 1.5$
00464841+0715177	M9	BPMG	77.0	26.9	$15.0^{+0.1}_{-0.3}$	$33.8^{+2.8}_{-3.2}$	$3.2 \pm 1.7$
00581143-5653326	(L6.1)	ARG	80.4	32.9	$10.3^{+0.3}_{-0.3}$	$25.3^{+2.8}_{-2.4}$	$2.6 \pm 2.0$
01525534-6329301	(M4.7)	BPMG	71.4	22.1	$107.6^{+6.8}_{-7.8}$	$23.7 \pm 2.4$	$14.7 \pm 1.7$
02534448-7959133	M5.5	BPMG	50.1	30.9	$66.9 \pm 4.9$	$28.9^{+2.8}_{-3.2}$	$12.0 \pm 2.1$
03390160-2434059	M5.9	COL	77.8	31.9	$204.7^{+6.6}_{-3.5}$	$59.4^{+3.6}_{-6.0}$	$18.6 \pm 1.8$
03473987-4114014	(M5.3)	COL	38.0	45.4	$77.2^{+11.0}_{-10.5}$	$71.0^{+8.8}_{-8.0}$	$19.7 \pm 1.7$
03510460-5701469	(M5.1)	COL	17.6	47.4	$88.3^{+12.0}_{-11.7}$	$68.6^{+8.8}_{-8.0}$	$19.1 \pm 1.7$
03550477-1032415	M8.5	BPMG	39.5	38.5	$26.4^{+3.5}_{-4.2}$	$35.0^{+4.4}_{-4.8}$	$17.7 \pm 1.8$

<sup>a</sup> Spectral types in parentheses were estimated from **2MASS–AllWISE** colors (see Section 4.1).

<sup>b</sup> The binary hypothesis is more probable than the single hypothesis (see Section 3).

This table is available in its entirety in the online journal. The complete table has 252 rows.

## 7. A SEARCH FOR NEW COMMON PROPER MOTION PAIRS

Since the **2MASS** and **AllWISE** catalogs provide a fast way to determine proper motions for a large number of targets, we performed a search for common proper motion objects around all candidates in the **BASS** sample. We used the **BANYAN II** statistical distance of each candidate to define a projected separation radius of 10,000 AU within which we have searched for any other object with a proper motion respecting the criteria of Lépine & Bongiorno (2007), albeit with a more conservative filter on allowed proper motion difference. This requires that the separation  $\Delta\theta$  (measured in arc seconds) and the proper motion difference  $\Delta\mu$  (measured in mas yr<sup>-1</sup>) obey the following equations :

$$\Delta\theta \Delta\mu < 1,000 \cdot (\mu/150)^{3.8},$$

$$\Delta\mu < 50.$$

These criteria should ensure that the majority of genuine proper motion pairs are recovered, with a minimal amount of contamination from chance alignments. This search allowed us to find 5 new common proper motion pairs and recover 10 which were already known in the literature. Those already known are :

- **2MASS J00451358+0015509\*** (M3.8) and **2MASS J00451098+0015117** (HD 4271; F8; Newton et al. 2014)
- **2MASS J01243060–3355014\*** (GJ 2022 B; M4.5) and **2MASS J01242767–3355086** (GJ 2022 AC; M5+M5; Thé & Staller 1974)
- **2MASS J02033222+0648588\*** (estimated M4.5) and **2MASS J02032589+0648008** (estimated early-M; Zacharias et al. 2012)
- **2MASS J02420204–5359147\*** (M4.6) and **2MASS J02420404–5359000** (estimated early-M; (Zacharias et al. 2012))
- **2MASS J03114240–1537183\*** (LP 722–14; estimated M5.0) and **2MASS J03114269–1537327** (LP 722–15; estimated M2.2; Luyten 1977)
- **2MASS J03283911–1537333\*** (GJ 3229 B; M3.5) and **2MASS J03283893–1537171** (GJ 3228 A; M3.5; Gliese & Jahreiß 1991)



- 2MASS J03505949+1414017\* (M5) and 2MASS J03510078+1413398 (M4; Mason et al. 2001)
- 2MASS J21440795+1704372\* (G 126–30; M4.5) and 2MASS J21440900+1703348 (G 126–31; M4; Mason et al. 2001)
- 2MASS J23225240–6151114\* (M5) and 2MASS J23225299–6151275\* (L2 $\gamma$ ; Gagné et al. 2014c)
- 2MASS J23102196–0748531\* (M5) and 2MASS J23102471–0748432 (HIP 114424; K0; Mann et al. 2014)

We identified components present in the *BASS* or *LP-BASS* catalogs with an asterisk. Any potentially useful information from these matches were already taken into account in Section 4. We discuss the new potential common proper motion pairs below :

2MASS J04353042–6449570 from *BASS* (estimated M8.4 with  $J = 15.27$ ) seems to be co-moving with 2MASS J04352709–6450042 ( $J = 15.16$ ) at an angular separation of 22.''4 and a proper motion difference of 0.4 mas yr<sup>-1</sup> (0.05 $\sigma$ ) with respect to a total proper motion of 53.2 mas yr<sup>-1</sup>. However, we note that 2MASS J04352709–6450042 is only 0.11 magnitudes brighter in the  $J$  band, and yet its NIR colors are significantly bluer : it has  $J - K_S = 0.42$  and  $H - W2 = 0.02$ , versus  $J - K_S = 1.34$  and  $H - W2 = 1.30$  for the *BASS* candidate. These very blue colors would be indicative of a spectral type earlier than M, which is not consistent with it being at the same distance from the primary, even if the latter was a multiple system. For this reason, *BANYAN II* rejects it as a probable candidate member of CAR, but if we do not include photometry, then its Bayesian probability for CAR is 31.4%, with a contamination probability of 21.9%. We conclude nonetheless that the secondary is most probably not a member of CAR and that this system is possibly a chance alignment, since otherwise it would be hard to reconcile the very different colors and the similar apparent  $J$  magnitudes of its components. We note that Lépine & Bongiorno (2007) used their common proper motion criteria only on stars with  $\mu > 150$  mas yr<sup>-1</sup> hence it is possible that it does not perform as well on this system which has only  $\mu = 53.2$  mas yr<sup>-1</sup>.

2MASS J05121347+0131539 (NLTT 14667) from *LP-BASS* (estimated M4.9 with  $J = 10.36$ ) seems to be co-moving with 2MASS J05121170+0131154 ( $J = 16.39$ ) at an angular separation of 46.''8 and a proper motion difference of 28.6 mas yr<sup>-1</sup> (0.9 $\sigma$ ) with respect to a total proper motion of 212.4 mas yr<sup>-1</sup>. The contrast is significant with  $\Delta J = 6.03$ , which would point to a late-T spectral type for the secondary if it is at the same distance than the primary. However, we note that the secondary is most probably a contaminating object, since an extended PSF is visible within 10'' of its 2MASS position in the red *DSS* filter.

2MASS J14415883–1649008 (WT 2090) from *LP-BASS* (M4.5 with  $J = 10.23$ ) is co-moving with 2MASS J14415908–1653133 (Wolf 1501; M3 with  $J = 9.35$ ) at an angular separation of 252.''5 and a proper motion difference of 3.8 mas yr<sup>-1</sup> (0.3 $\sigma$ ) with respect to a total proper motion of 290.3 mas yr<sup>-1</sup>. Kirkpatrick et al. (2010) obtained a NIR spectral type of M3 for Wolf 1501. We note that the contrast ratio  $\Delta J = 0.88$  is large for their respective spectral types of M3 and M4.5. Both

objects are weak candidate members of ABDMG, with respective Bayesian probabilities of 5.4% and 3.8% and contamination probabilities of 23.4% and 26.9%.

2MASS J21500933+0558102 from *LP-BASS* (estimated M4.9 with  $J = 10.66$ ) is co-moving with 2MASS J21501011+0558137 from *LP-BASS* (estimated M4.9 with  $J = 10.74$ ) at an angular separation of 12'' and a proper motion difference of 21.9 mas yr<sup>-1</sup> (0.8 $\sigma$ ) with respect to a total proper motion of 146.9 mas yr<sup>-1</sup>. Their contrast ratio is relatively small with  $\Delta J = 0.08$ , which is consistent with their similar estimated spectral types. The direction of their 2MASS-*AllWISE* proper motions is slightly different, which favors ARG for the primary and  $\beta$ PMG for the secondary. However, both have a somewhat ambiguous membership between ARG and  $\beta$ PMG; the primary has respective Bayesian probabilities of 8.0% and 15.6%, whereas the secondary has 16.6% and 3.0%. We thus regard this system as an ambiguous, low-probability candidate member of  $\beta$ PMG and ARG.

2MASS J23133055–5352079 from *LP-BASS* (estimated M5.7 with  $J = 12.08$ ) is co-moving with 2MASS J23133024–5351389 (HD 219046;  $J = 8.59$ ) at an angular separation of 29.''1 and a proper motion difference of 17.0 mas yr<sup>-1</sup> (1.5 $\sigma$ ). The contrast ratio is consistent with the latter component being a K-type star. We find no additional information in the literature for this system.

## 8. A PRELIMINARY INVESTIGATION ON MASS SEGREGATION

According to the virial theorem, it is expected that all components of a gravitationally bound astrophysical system will end up with the same average kinetic energy after relaxing to the equilibrium state. Hence, lower-mass members of associations of stars are expected to have a larger velocity than their higher-mass siblings; this effect is called mass segregation. It has already been demonstrated for globular clusters (Hasan & Hasan 2011; Olczak et al. 2011; Pang et al. 2013), however no signs of mass segregation have yet been identified for YMGs. The *BASS* catalog provides a unique sample on which to test for this effect, since it potentially contains the latest-type, lowest-mass members known to all YMGs.

Instead of relying on mass estimates which are dependent on physical hypotheses inherent to evolutionary models, we use statistical distance predictions from *BANYAN II* to obtain absolute  $W1$  magnitudes for all high probability candidates in the *BASS* sample. Since members of YMGs are expected to be coeval, their absolute  $W1$  magnitude should depend on their mass in a monotonic way, thus providing a more direct way to bring out mass segregation. The *AllWISE*  $W1$ -band is preferred to 2MASS bands since it is less affected by clouds in the atmospheres of BDs, which could introduce errors in the absolute magnitude–mass relation. Since the  $UVW$  separation to the center of mass of a given YMG is directly related to the kinetic energy of a member with respect to the YMG, it is expected that mass segregation would cause fainter (less massive) objects to be more scattered in the  $UVW$  space (i.e. dynamical mass segregation). As a consequence of this, one would also expect that they be more scattered spatially at a given moment in the  $XYZ$  space (i.e. spatial mass segregation).

Allison et al. (2009) devised a quantitative way to assess mass segregation in associations of stars, which is more sensitive than a simple visual characterization, and more impor-

tantly does not depend on the geometry of the members' distribution. They base this characterization on the principle of *Minimum Spanning Trees* (MSTs). For a given distribution of coordinates (e.g. RA and DEC in a bi-dimensional space which is most often used in the case of open clusters), a MST is the shortest network of straight lines that connects all individual points without creating any loop. A mass segregation ratio (MSR) is then defined as :

$$\Lambda_{\text{MSR}} = \frac{\langle l_{\text{norm}} \rangle}{l_{\text{massive}}} \pm \frac{\sigma_{\text{norm}}}{l_{\text{massive}}},$$

where  $l_{\text{massive}}$  is the total length of the MST of the  $N$  most massive stars in an association, and  $\langle l_{\text{norm}} \rangle$  and  $\sigma_{\text{norm}}$  are respectively the average and standard deviation of a set of Monte Carlo simulations in which the MST network length is determined for a set of  $N$  stars randomly selected from the sample. If mass segregation is present, it is expected that  $\Lambda_{\text{MSR}}$  will have a value above unity. On the other hand, a value below unity would indicate that massive stars are more scattered than other members. We performed this analysis in both the XYZ and UVW 3-dimensional spaces, using the algorithm described by Cartwright & Whitworth (2004) to build MSTs. We determined the MSR for values of  $N$  spanning 3 to the total number of stars in each YMG, using 100 random subsets in each Monte Carlo simulation. We show resulting MSTs for the full set of  $N$  high bona fide members and high probability *BASS* candidates of each YMG in Figures 8–9. We sorted stars according to their increasing absolute  $W1$  magnitudes instead of decreasing mass when we determined  $\Lambda_{\text{MSR}}$ , for the reasons mentioned above. This was done for only bona fide members in a first step, and then for bona fide members and all high probability candidates of the *BASS* catalog taken together.

We show in Figures 10–11 the resulting MSRs as a function of  $N$  for only bona fide members of each YMG. A MSR larger than one indicates that massive stars are more concentrated towards the center of the distribution, whereas a MSR smaller than one indicates the inverse situation. In most cases with a large statistical significance, the MSR ratio is above unity, which is expected from the physical considerations mentioned above. ABDMG is the only case where both the maximal spatial and dynamical mass segregation are present at  $> 2\sigma$ , with  $2.5\sigma$  and  $2.4\sigma$ , respectively.  $\beta$ PMG displays a spatial mass segregation at  $2.4\sigma$  and COL displays a dynamical mass segregation at  $2.9\sigma$ . In some cases ( $\beta$ PMG, TWA and THA), an inverse spatial or dynamical mass segregation is apparent between  $1\sigma$  and  $2\sigma$ , but never at a larger statistical significance. The inclusion of high priority *BASS* candidates in this analysis (see Figures 12–13) generally increases the significance of the previous results, the only exception being COL. As a consequence, ABDMG, THA and COL display both a maximal dynamical and spatial mass segregation at  $2\text{--}4\sigma$  in this situation. Spatial segregation is also apparent for ARG and BPMG at  $3.2\sigma$  and  $3.4\sigma$ , respectively. We note that in most cases which are statistically significant, mass segregation only starts appearing at masses lower than  $0.3\text{--}0.5 M_{\odot}$ . However, we stress that a follow-up of the *BASS* sample must be completed before cases other than ABDMG can be considered as significant. We add that even in the case of ABDMG, securing more members will be necessary to increase the statistical significance of this tentative result.

Our analysis does not take account of two effects that could bias our results; (1) the selection criteria imposed to the *BASS* survey; and (2) the effect of unresolved binaries. To investigate the former effect, we performed a Monte Carlo simulation in which we have drawn a million synthetic objects from each SKM, and rebuilt 500 times the MST corresponding to a random subset of 100 synthetic objects. We repeated this with and without applying the selection filters described in Section 2 to assess whether they have any systematic effect on the length of the MST. Any such systematic bias will only affect *BASS* candidates, which all have masses lower than currently known bona fide members. Hence, if this bias systematically shrinks the MST length, we will have underestimated mass segregation in the analysis described above, and vice versa. We found that our selection bias did not significantly affect the dynamical mass segregation: in all cases, they decreased the length of the dynamical MST with a statistical significance between 0 and  $0.1\sigma$ . However, the spatial mass segregation was affected by our selection filters: in all cases, the average length of the MST has also decreased, with statistical significances of  $\sim 1.5\sigma$  (ABDMG),  $\sim 1.8\sigma$  (ARG and TWA),  $\sim 2.2\sigma$  (CAR),  $\sim 2.8\sigma$  ( $\beta$ PMG) and  $\sim 3\sigma$  (COL; THA was unaffected). We have thus likely underestimated any positive spatial mass segregation in our analysis, as well as overestimated any negative spatial mass segregation. Since all of the statistically significant spatial mass segregation ratios obtained here are positive (less massive objects are more spread out), this does not change the conclusions of our analysis, except that we might generally underestimate the statistical significance of these conclusions.

Since we did not account of known and unknown unresolved binaries in our analysis and because the  $W1$  flux of an object always falls rapidly when decreasing its mass, we will have systematically overestimated the total mass of unresolved systems. However, there is no apparent reason that would cause the fraction of multiple systems in a given YMG to correlate with XYZUVW. Hence, the effect of ignoring unresolved systems will be the same as overestimating the mass and luminosity of a random subset of members that we considered isolated. This addition of noise will thus tend to draw the MSR closer to unity, as well as increase the measurement error on the MSR. As a consequence, this simplification will have made us less sensitive to the detection of any mass segregation, whether it be positive or negative.

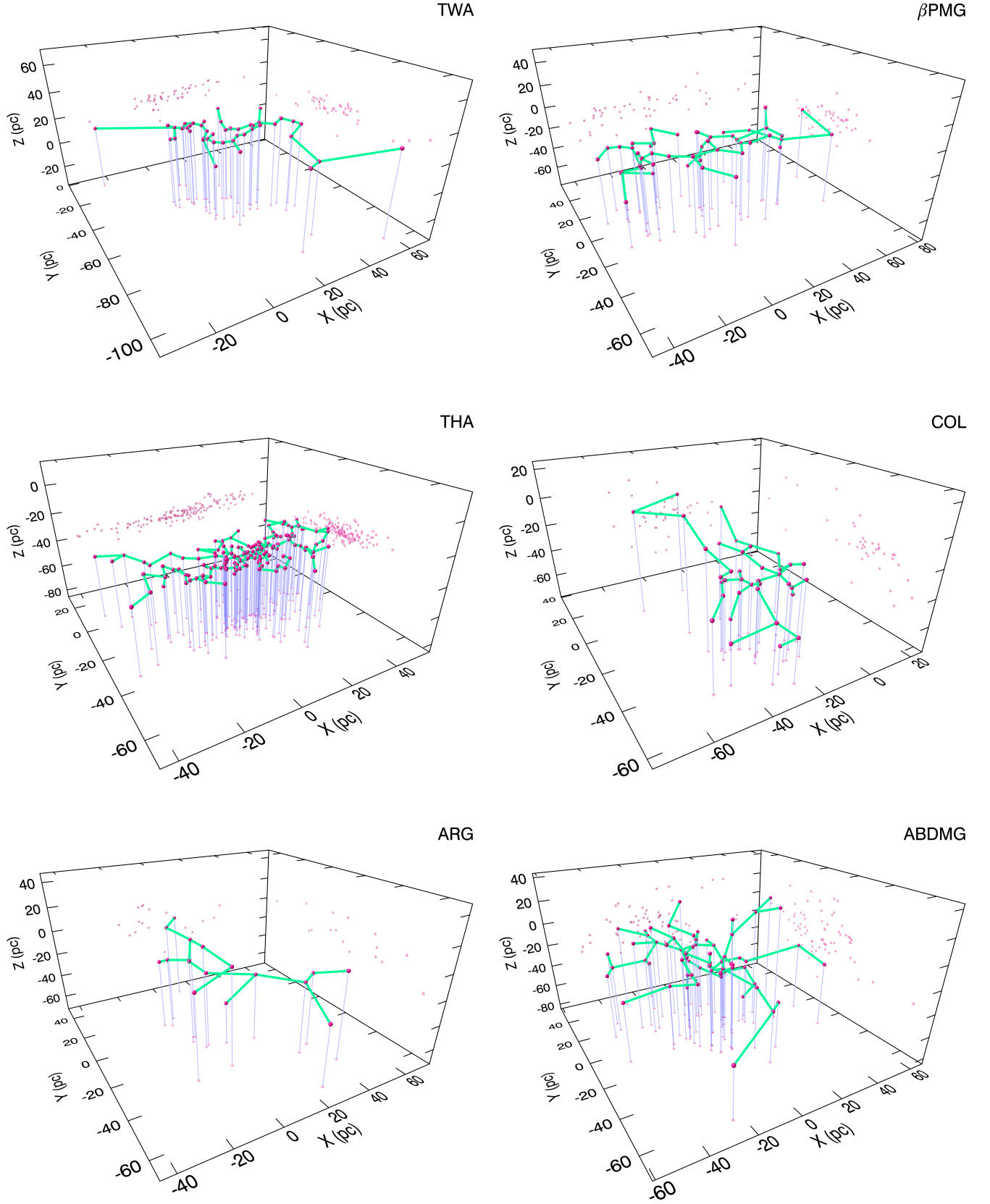


FIG. 8.— Minimum spanning trees (MSTs; green lines) in XYZ space for bona fide members and high probability *BASS* candidates (red points and their projections). Blue lines link each data point to its projection on the XZ plane for clarity. The total length of the MSTs for the brightest subsets of objects, compared with a random subset, is a useful diagnosis to determine the presence of mass segregation.



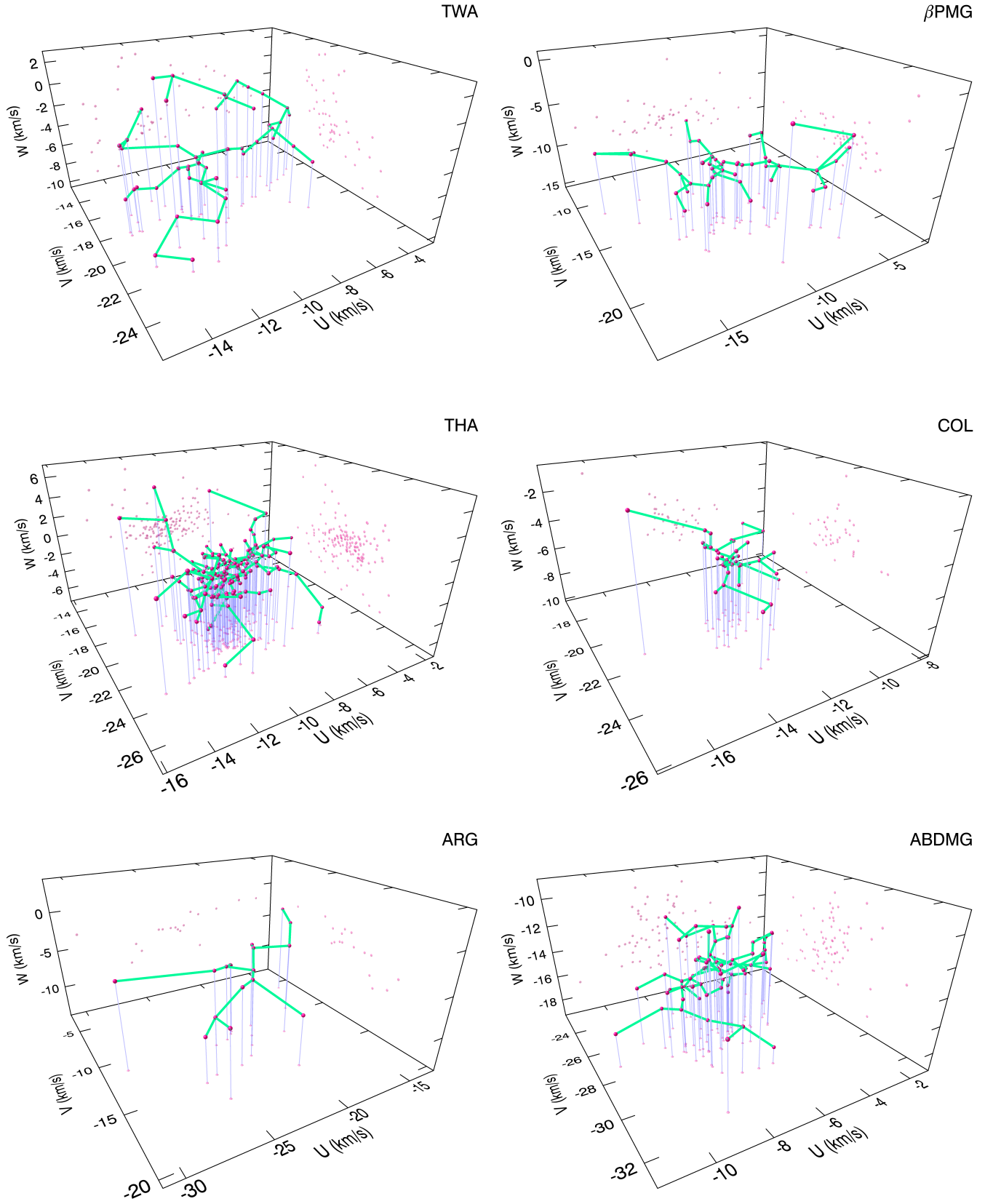


FIG. 9.— Minimum spanning trees (MSTs; green lines) in  $UVW$  space for bona fide members and high probability *BASS* candidates (red points and their projections). Blue lines link each data point to its projection on the  $UV$  plane for clarity. The total length of the MSTs for the brightest subsets of objects, compared with a random subset, is a useful diagnosis to determine the presence of mass segregation.

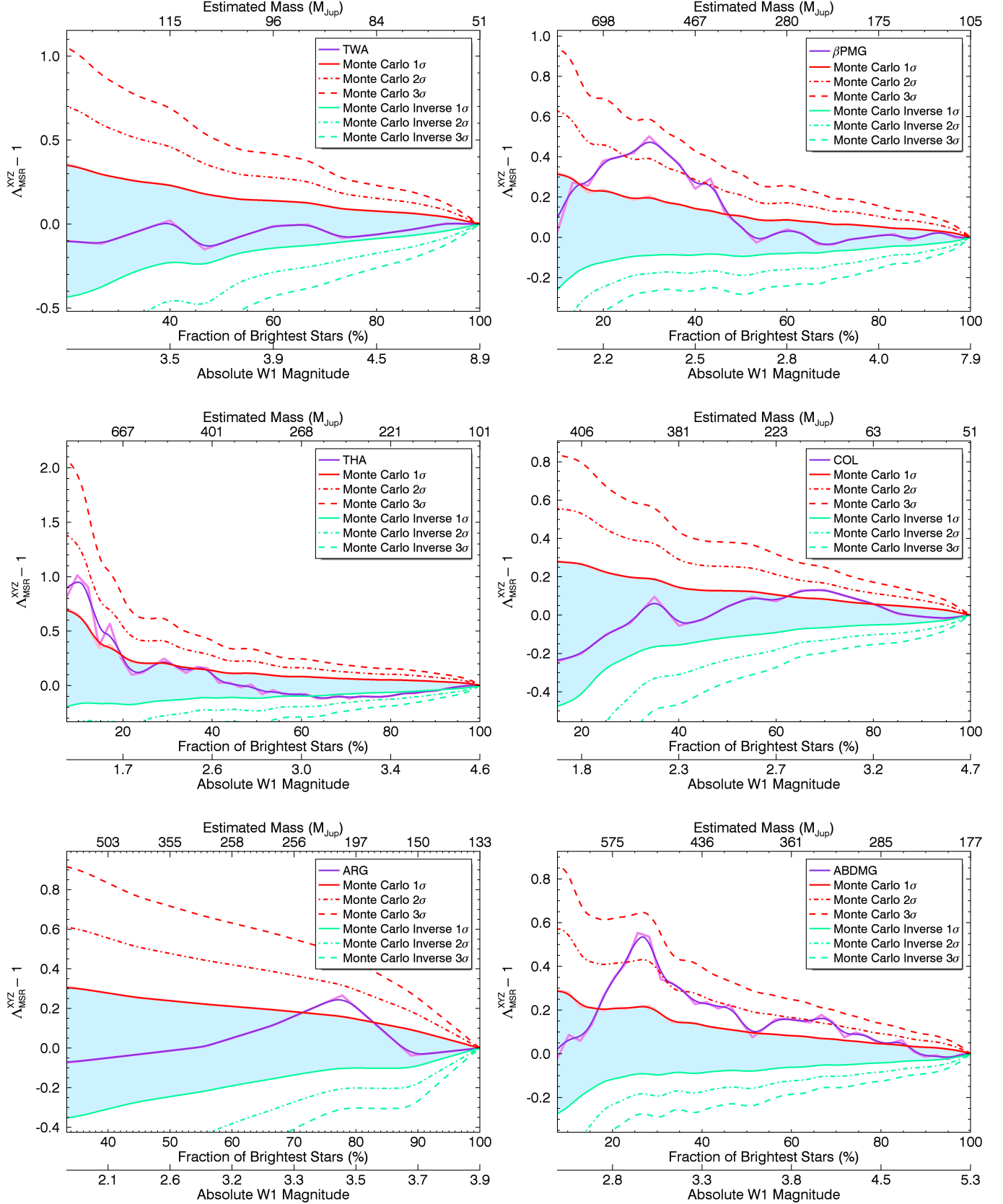


FIG. 10.— Spatial mass segregation ratios (MSRs) for bona fide members of YMGs considered here except CAR, as a function of the population fraction of brightest stars that were used in the calculation. Purple curves represent the departure of the MSR from unity, whereas red curves represent results of the Monte Carlo simulation where random stars were chosen instead of the brightest ones. Green curves delimit the region below which the MSR would be smaller than unity with statistical significance (i.e. least massive stars more concentrated towards the center). A MSR (purple curve) located inside the pale blue region indicates no significant difference between the scatter of the brightest or faintest objects. Darker, thick lines represent smoothed versions of the light-colored lines. The segregation mass ratio of CAR does not significantly depart from unity for any value of  $N$ .

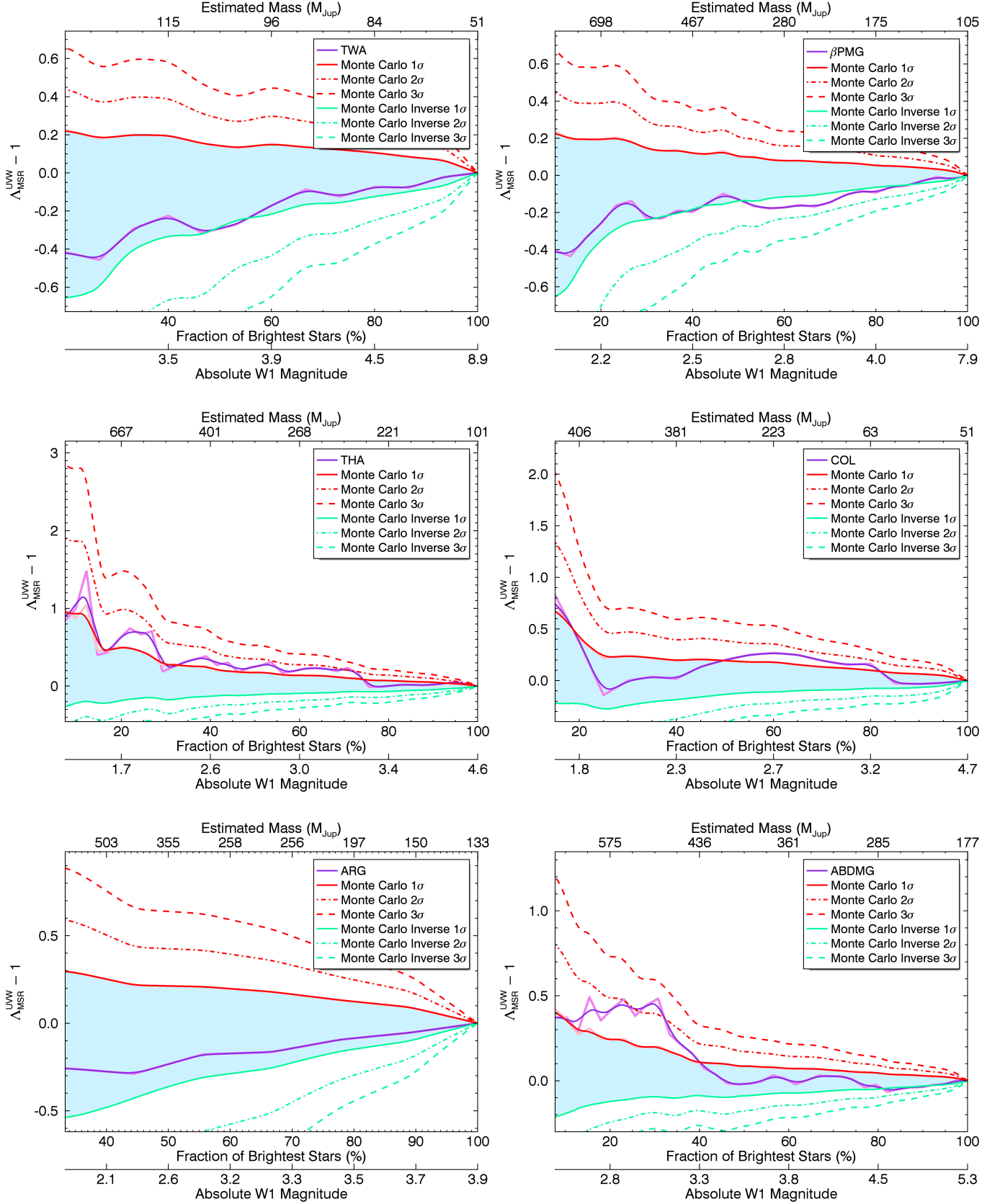
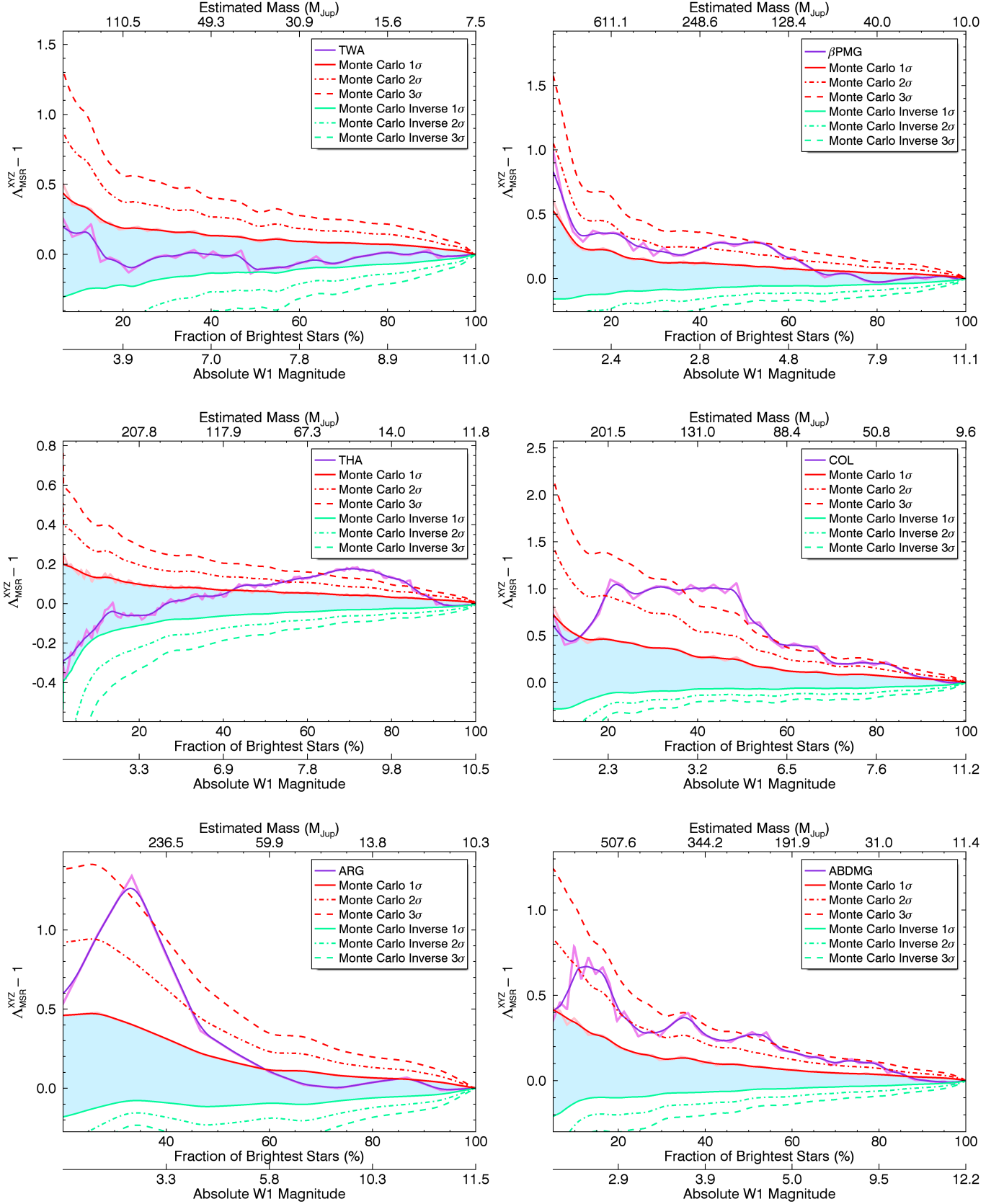


FIG. 11.— Same as Figure 10 for dynamical mass segregation.



FIG. 12.— Same as Figure 10 with high probability *BASS* candidates added to the set of bona fide members.

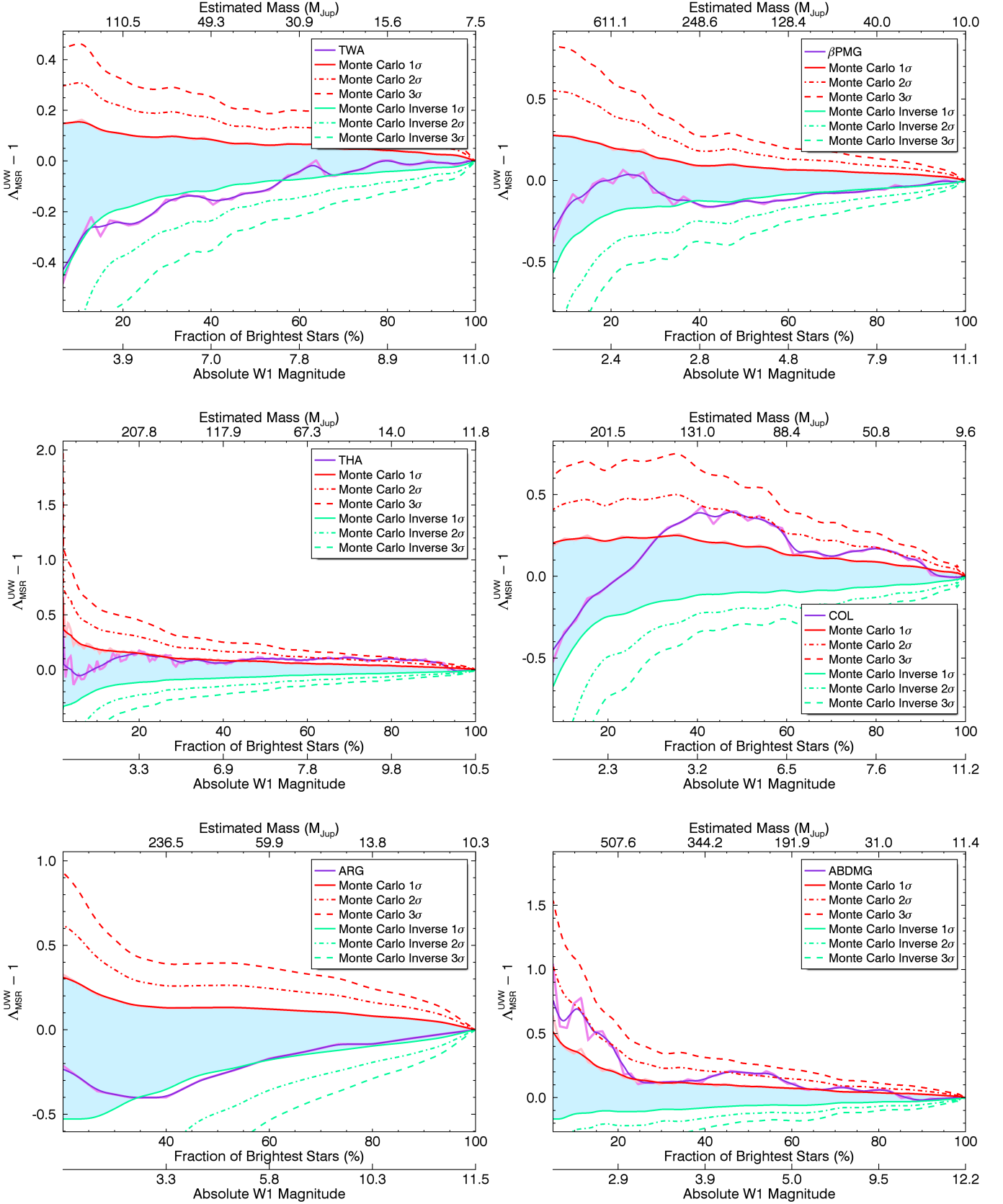


FIG. 13.— Same as Figure 11 with high probability *BASS* candidates added to the set of bona fide members.

## AB Doradus

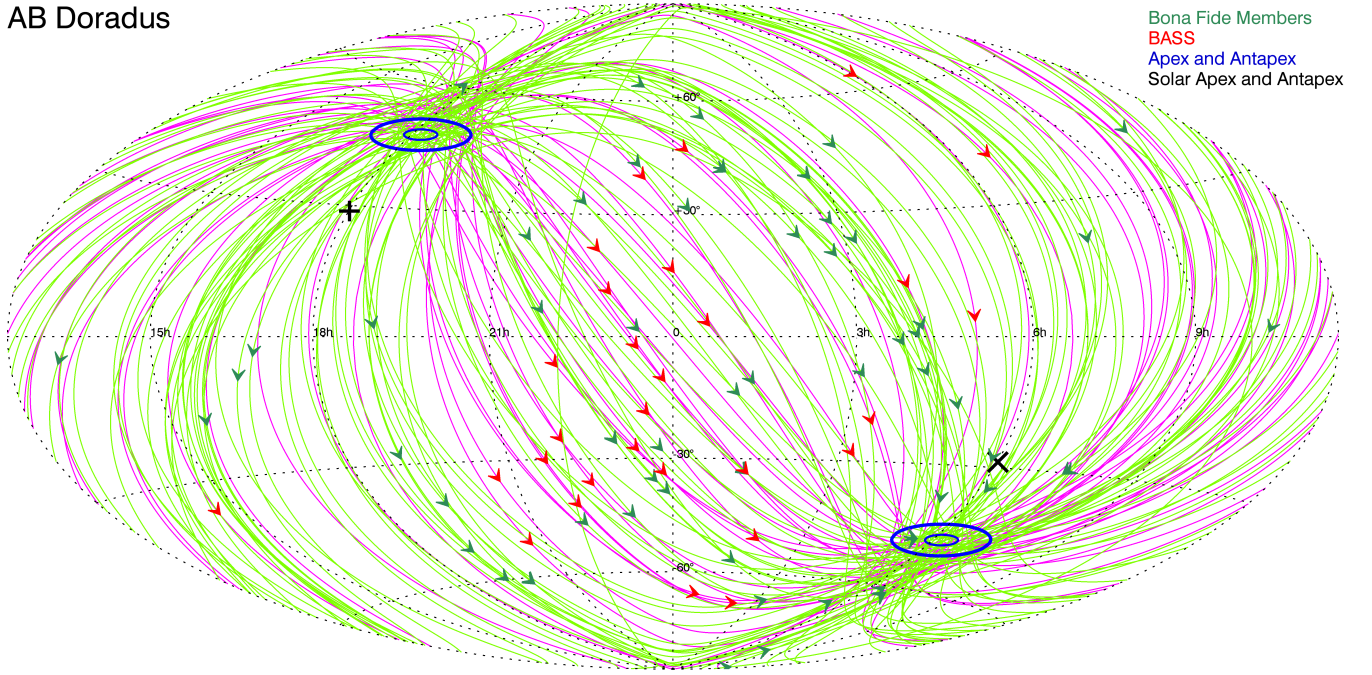


FIG. 14.— Proper motion as a function of sky position for candidate members of AB Doradus in the *BASS* Catalog (red arrows and lines), compared with currently known bona fide members (light green; see [Gagné et al. 2014c](#)). The proper motions of candidate members and bona fide members all converge to the apex and antapex of ABDMG (blue circles), which is a well known property of YMGs.

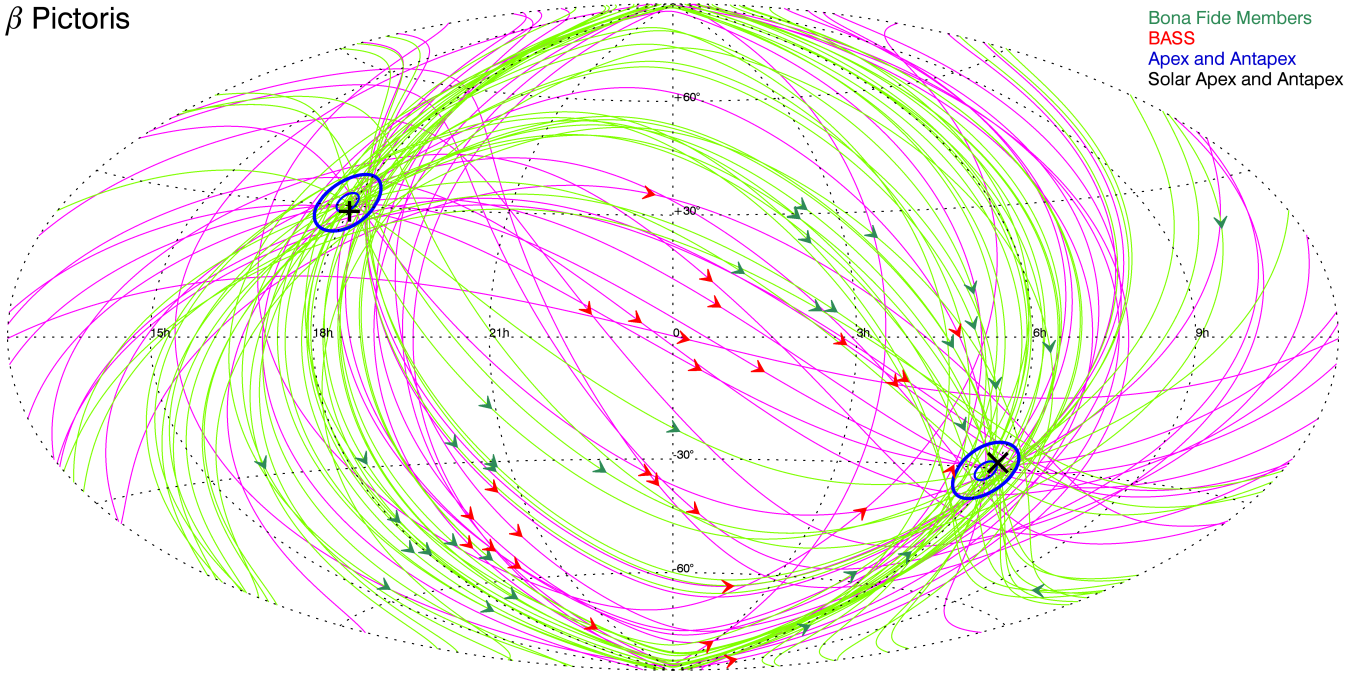
 $\beta$  Pictoris

FIG. 15.— Proper motion as a function of sky position for *BASS* candidate members and bona fide members of  $\beta$ PMG. Colors and symbols are defined in the same way as in [Figure 14](#).

## TW Hydrae

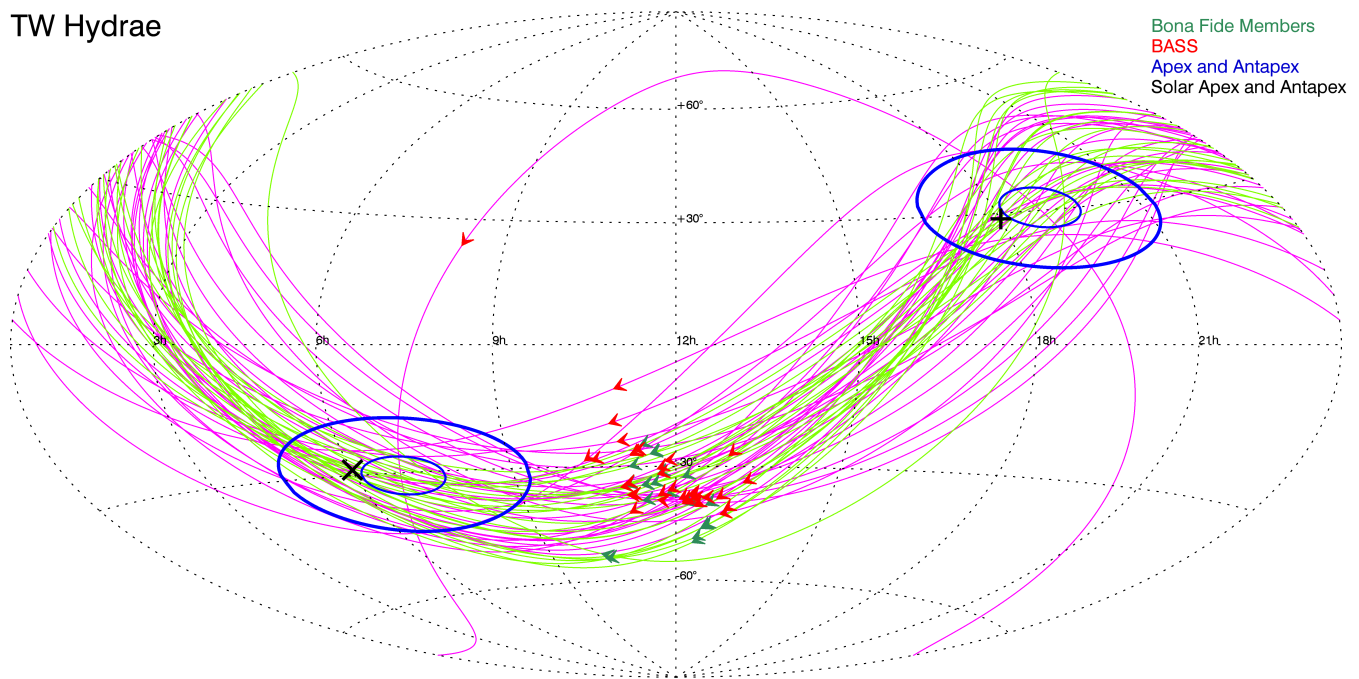


FIG. 16.— Proper motion as a function of sky position for *BASS* candidate members and bona fide members of TWA. Colors and symbols are defined in the same way as in Figure 14

## Carina

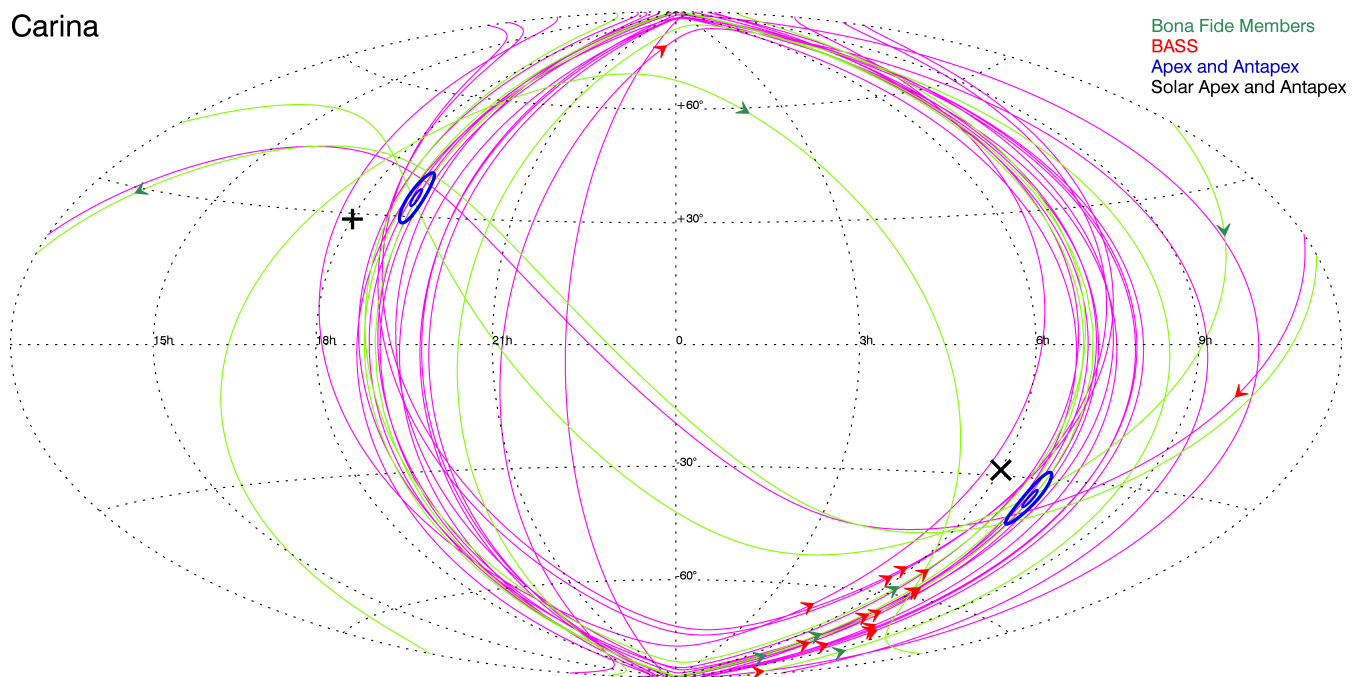


FIG. 17.— Proper motion as a function of sky position for *BASS* candidate members and bona fide members of CAR. Colors and symbols are defined in the same way as in Figure 14



## Tucana-Horologium

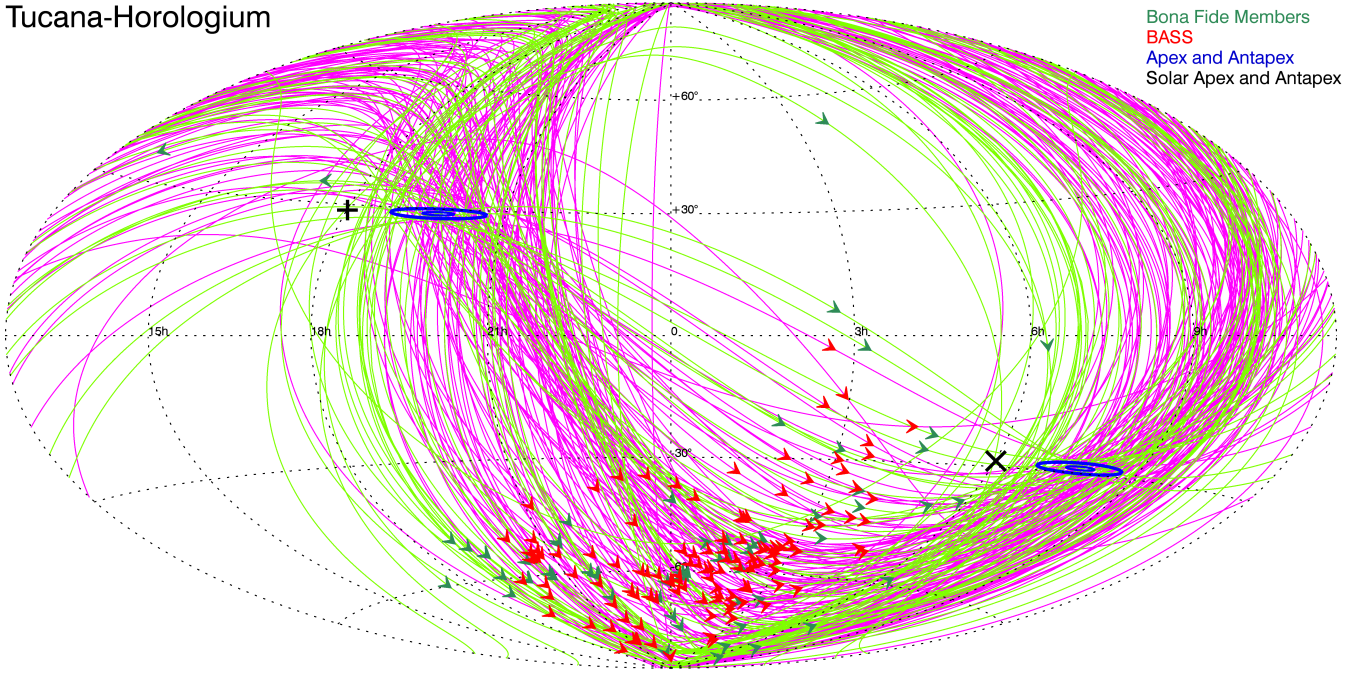


FIG. 18.— Proper motion as a function of sky position for *BASS* candidate members and bona fide members of THA. Colors and symbols are defined in the same way as in Figure 14

## Columba

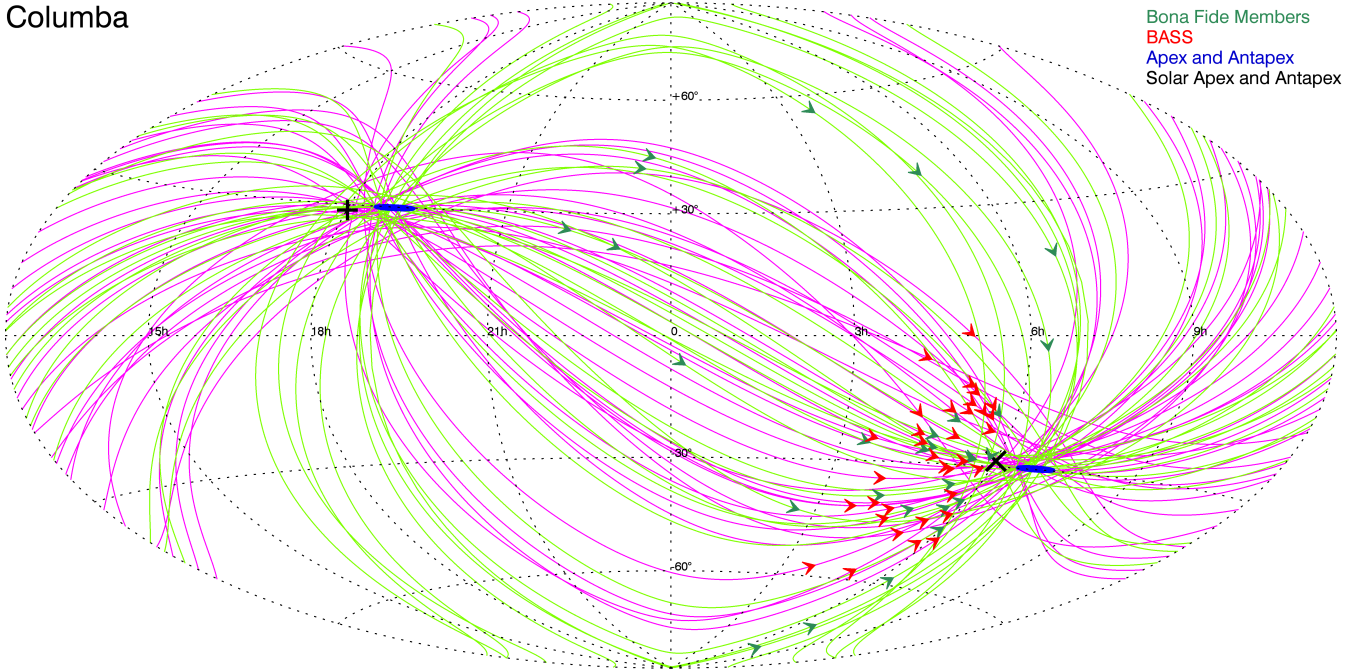


FIG. 19.— Proper motion as a function of sky position for *BASS* candidate members and bona fide members of COL. Colors and symbols are defined in the same way as in Figure 14

## Argus

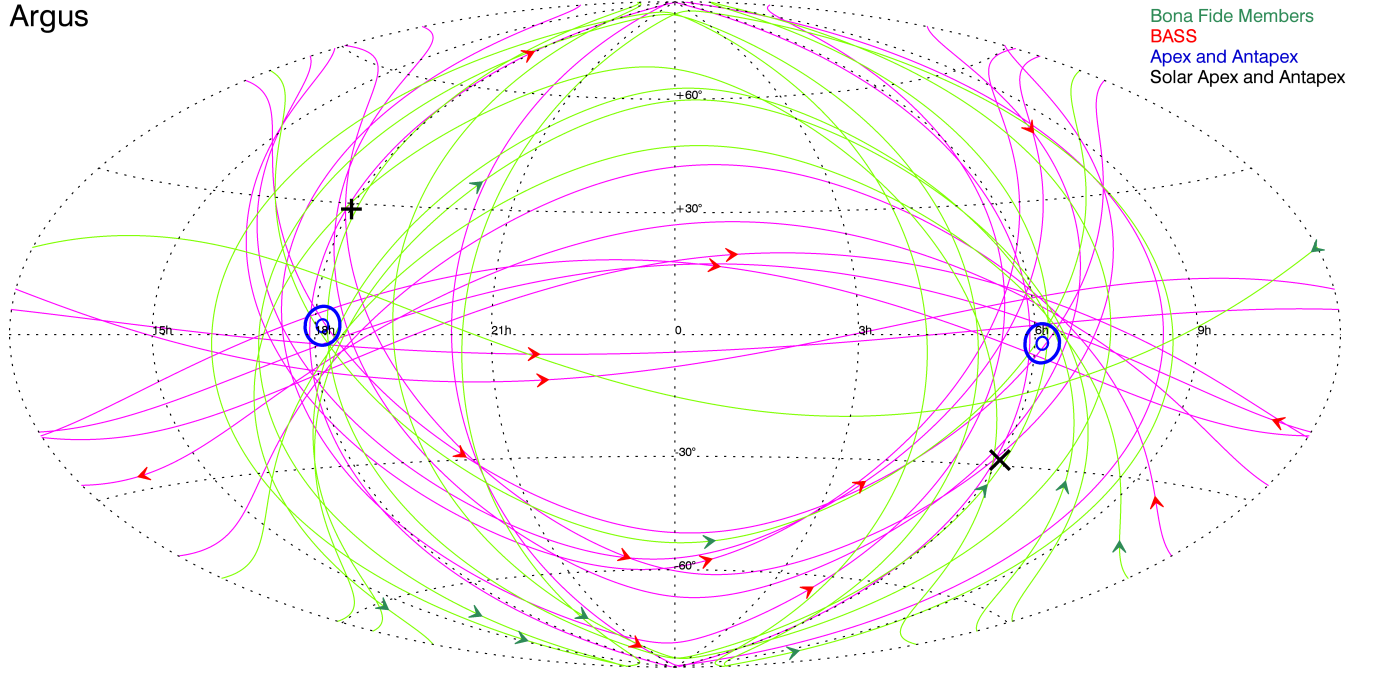


FIG. 20.— Proper motion as a function of sky position for **BASS** candidate members and bona fide members of ARG. Colors and symbols are defined in the same way as in Figure 14

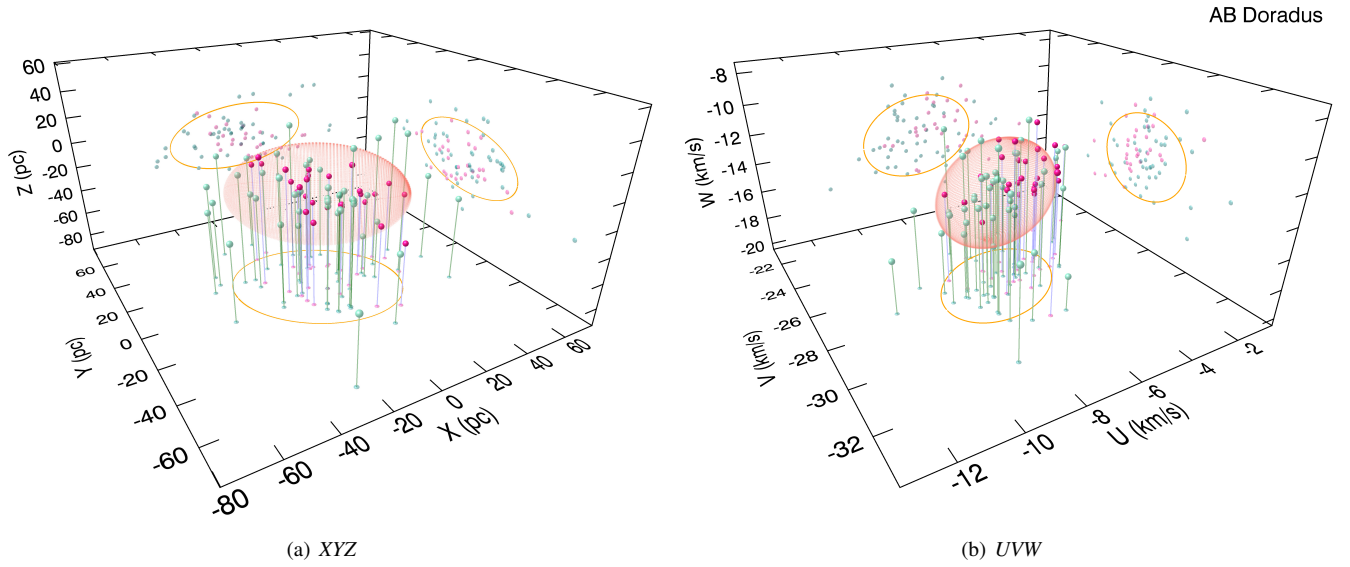


FIG. 21.— Most probable galactic positions  $XYZ$  and space velocities  $UVW$  based on **BANYAN II** statistical distances and RVs for all **BASS** candidate members in ABDMG (red points), compared with bona fide members (green points), as well as the spatial and kinematic ellipsoid models used in **BANYAN II** (orange ellipsoids; see Gagné et al. 2014c for more details). All points and models are projected on the three normal planes for a better clarity.

## 9. SUMMARY AND CONCLUSIONS

We used the *2MASS* and *AllWISE* surveys to perform the first systematic all-sky survey for  $\geq M5$  candidate members of YMGs. We identified a total of 275 M4–L7 candidate members, from which 153 are new strong candidates with an expected overall contamination of 13% from field stars, from which 79 are expected to be brown dwarfs, and 22 are expected to be planetary-mass objects. We searched for all additional information available in the literature for the *BASS* sample to update membership probability, and show that we recover 60% of known  $\geq M5$  candidates to YMGs, whereas most of the remaining 40% were missed due to the quality filters used to minimize false-positives. Three new common proper motion pairs were discovered among low-probability candidates. We finally used this unique sample to tentatively identify signs of mass segregation in YMGs. We find marginal evidence for mass segregation in ABDMG even when considering only bona fide members, and this result extends to THA and COL when high probability *BASS* candidates are taken into account. The *BASS* sample will open the door to the identification of BD members of YMGs, and has already proved extremely fruitful from a number of discoveries previously published. Extensive NIR and optical spectroscopic follow-ups are ongoing and have already enabled the discovery of several new young BDs which will be presented in upcoming papers. Complementary data can be found at our group’s website <http://www.astro.umontreal.ca/mbderg> and <http://www.astro.umontreal.ca/~gagne>, and the *BANYAN II* web tool is publicly available at <http://www.astro.umontreal.ca/~gagne/banyanII.php>.

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Caltech, under contract with NASA; the M, L, and T dwarf compendium housed at <http://DwarfArchives.org> and maintained by Chris Gelino, Davy Kirkpatrick, and Adam Burgasser.

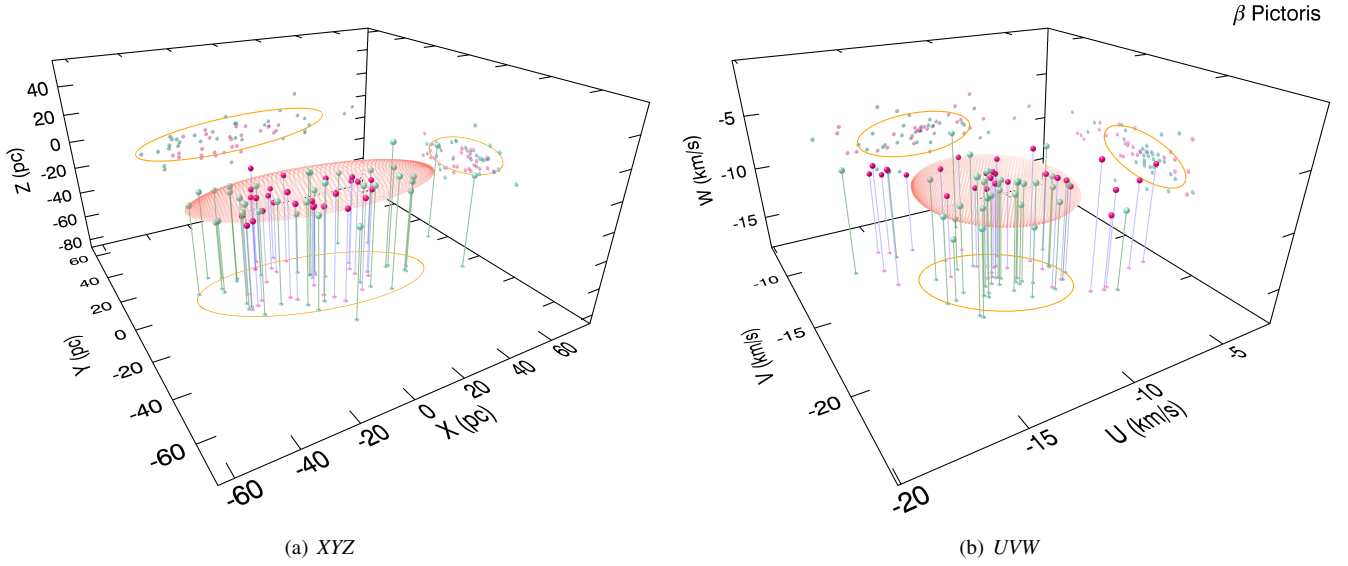


FIG. 22.— Most probable galactic positions  $XYZ$  and space velocities  $UVW$  based on **BANYAN II** statistical distances and RVs for all **BASS** candidate members in  $\beta$ PMG compared with bona fide members. Colors and symbols are defined in the same way as in Figure 21.

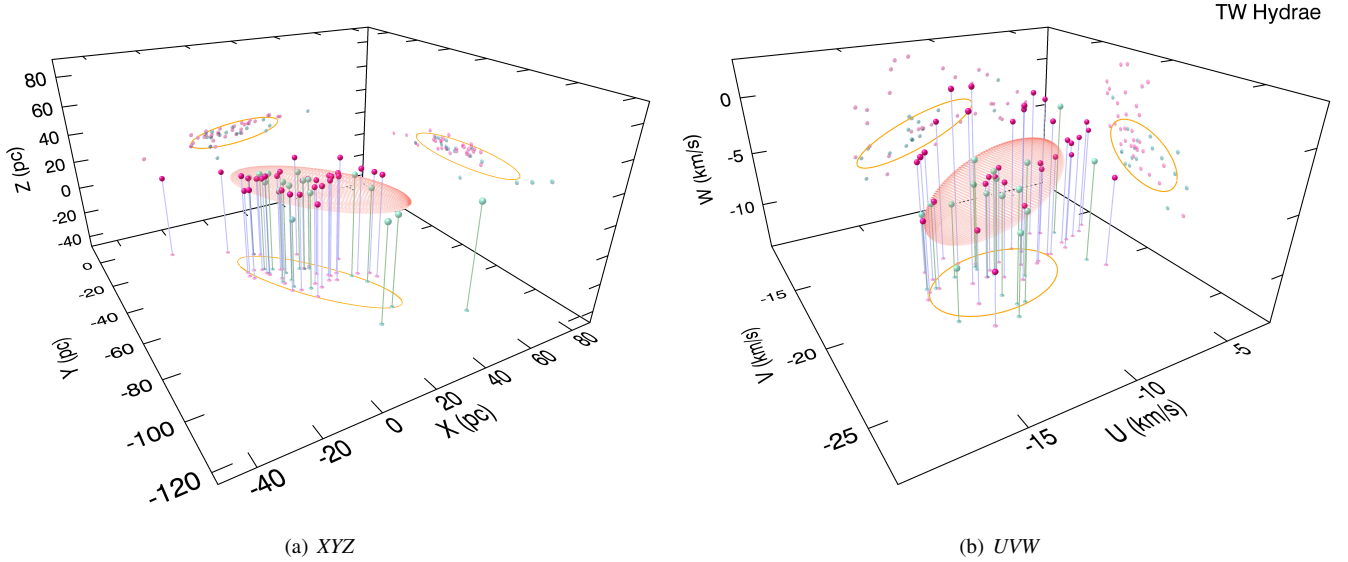


FIG. 23.— Most probable galactic positions  $XYZ$  and space velocities  $UVW$  based on **BANYAN II** statistical distances and RVs for all **BASS** candidate members in TWA compared with bona fide members. Colors and symbols are defined in the same way as in Figure 21. We note that a fraction of **BASS** candidates have kinematics slightly discrepant with those of TWA. It is possible that contamination from the Lower-Centaurus-Crux causes this (i.e. Schneider et al. 2012a), however a follow-up of these candidates will be needed to confirm this.



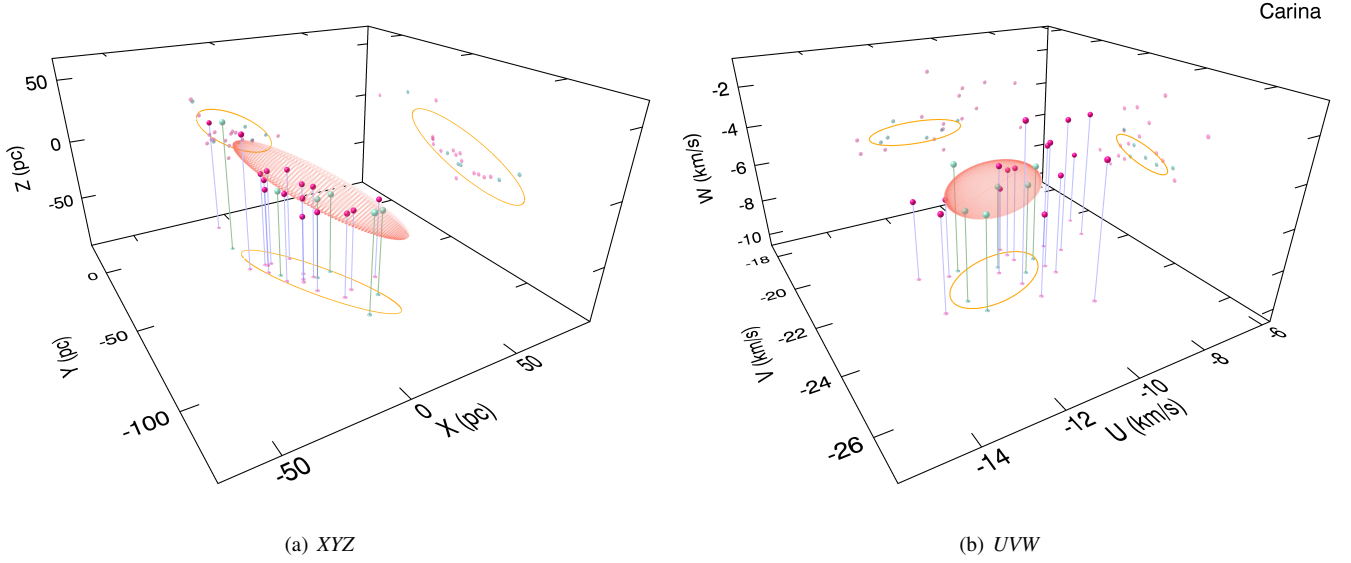


FIG. 24.— Most probable galactic positions  $XYZ$  and space velocities  $UVW$  based on **BANYAN II** statistical distances and RVs for all **BASS** candidate members in CAR compared with bona fide members. Colors and symbols are defined in the same way as in Figure 21. We note that the SKMs presented here (orange ellipsoids) are based on only 7 bona fide members, and they are thus most probably incomplete (see Gagné et al. 2014c for a discussion). It can be seen that **BASS** candidates preferentially fall in a region slightly outside of the kinematic model, which potentially points out to an overlooked region of CAR members in the kinematic space.

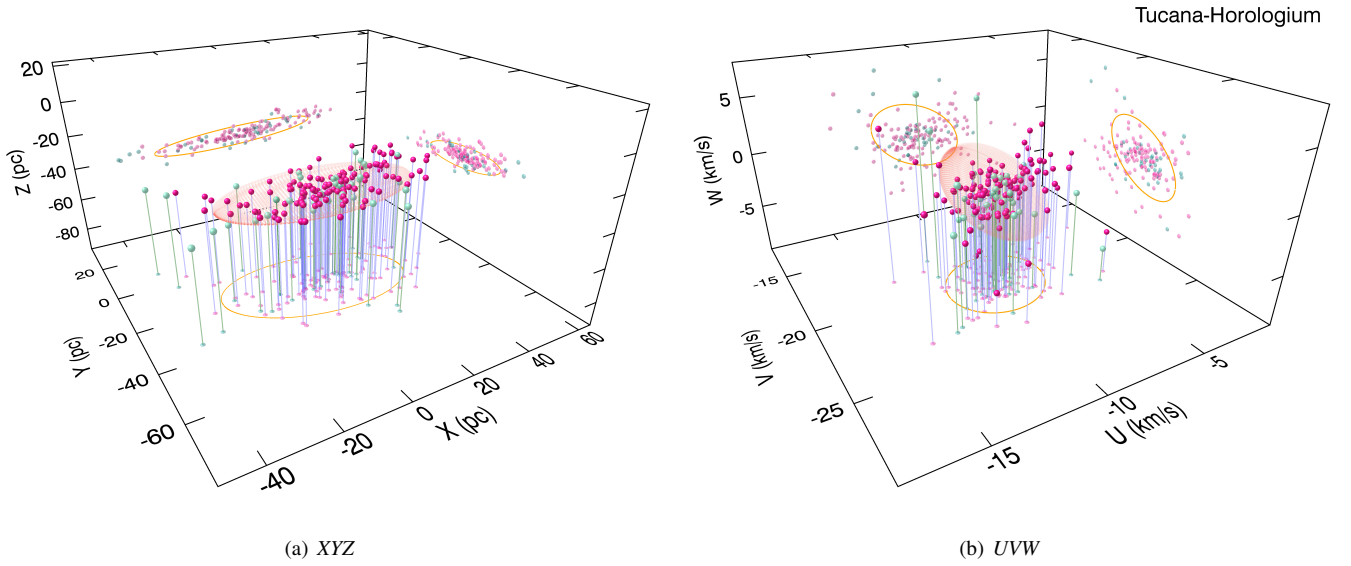


FIG. 25.— Most probable galactic positions  $XYZ$  and space velocities  $UVW$  based on **BANYAN II** statistical distances and RVs for all **BASS** candidate members in THA compared with bona fide members. Colors and symbols are defined in the same way as in Figure 21. As noted by Kraus et al. (2014), the spatial distribution of THA is significantly thinner in the  $Z$  direction and thus forms a plane in the  $XYZ$  space.

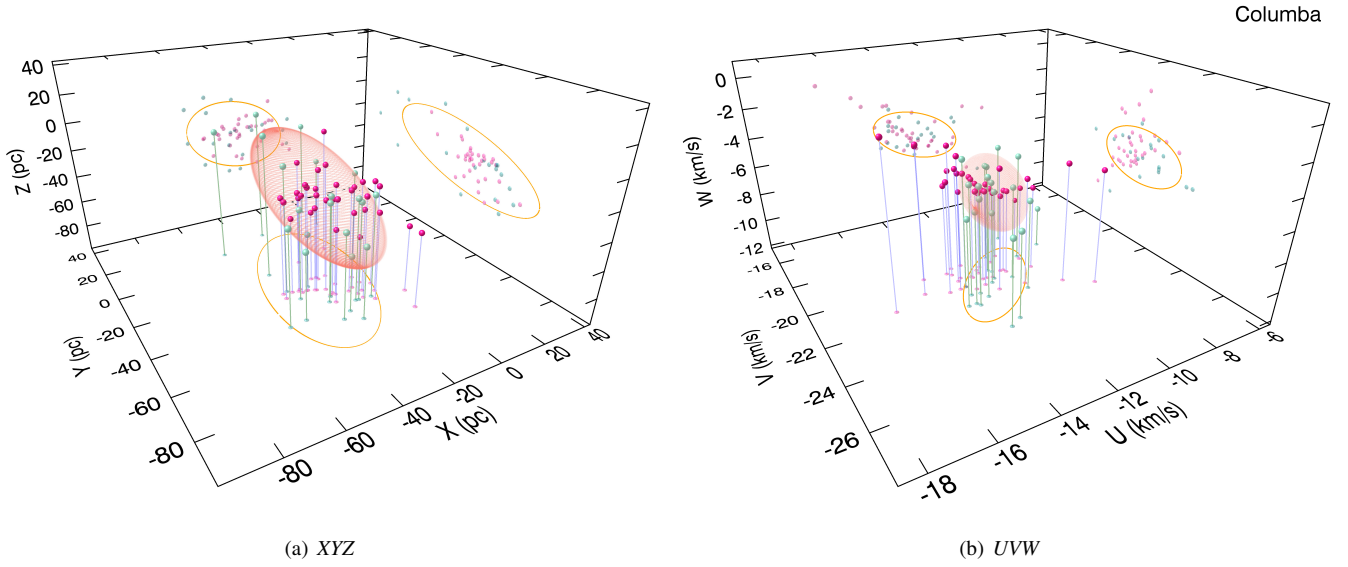


FIG. 26.— Most probable galactic positions  $XYZ$  and space velocities  $UVW$  based on **BANYAN II** statistical distances and RVs for all **BASS** candidate members in COL compared with bona fide members. Colors and symbols are defined in the same way as in Figure 21.

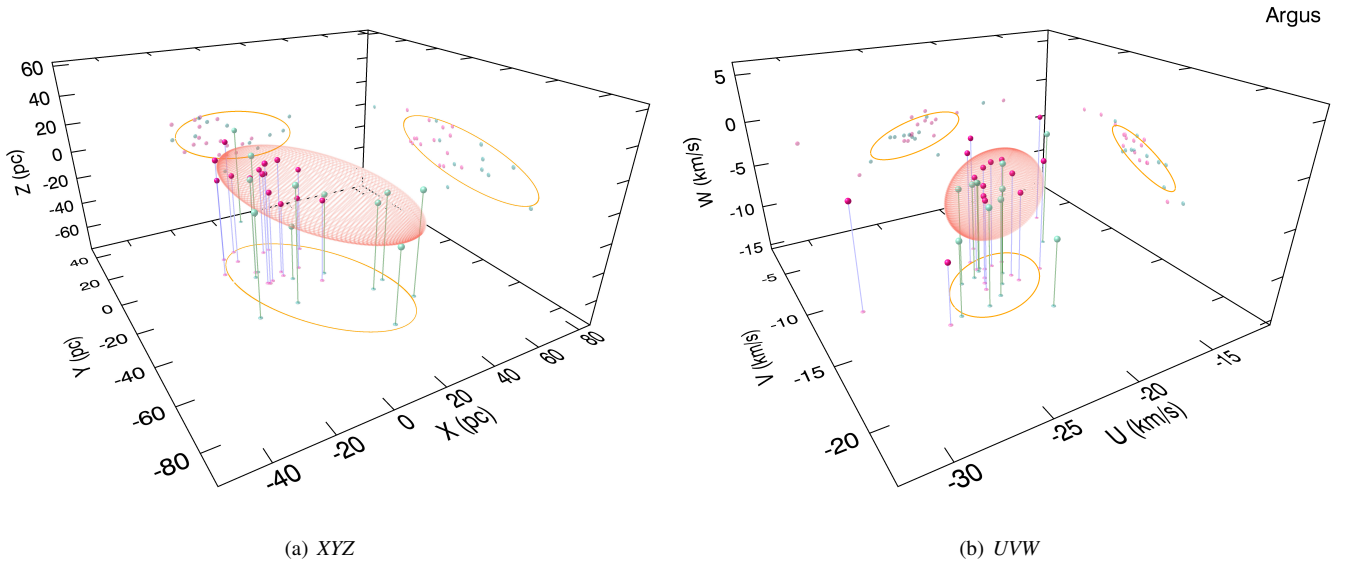


FIG. 27.— Most probable galactic positions  $XYZ$  and space velocities  $UVW$  based on **BANYAN II** statistical distances and RVs for all **BASS** candidate members in ARG compared with bona fide members. Colors and symbols are defined in the same way as in Figure 21.

## APPENDIX

APPENDIX A: THE INPUT SAMPLE OF NEARBY POTENTIAL  $> M5$  DWARFS

We present in [Table 6](#) the complete sample of 98 970 potential  $> M5$ , nearby objects in which we searched for candidate members to YMGs, which will might prove useful to study the kinematics of such red objects. This table includes all observables that were fed to [BANYAN II](#) to determine the Bayesian probability: [2MASS](#) and [AIIWISE](#) magnitudes, sky position and proper motion determined from the [2MASS–AIIWISE](#) cross-match. This list was built from the selection criteria described in [Section 2](#), which produced the two following SQL statements that we used to query the [2MASS](#) and [AIIWISE](#) all-sky catalogs, respectively, on the [IRSA](#) service :

• [2MASS](#) :

```
(GLAT > 15 OR GLAT < -15) AND (J_M-H_M) >= 0.506 AND (J_M-H_M) < 2 AND (H_M-K_M) >= 0.269 AND (H_M-K_M) < 1.6 AND (
NOT rd_flg LIKE '%0%') AND (NOT rd_flg LIKE '%6%') AND (NOT rd_flg LIKE '%9%') AND bl_flg = '111' AND cc_flg = '
000' AND gal_contam = '0' AND J_M > 2 AND H_M > 2 AND K_M > 2 AND (NOT ph_qual LIKE '%D%') AND (NOT ph_qual LIKE
'%E%') AND (NOT ph_qual LIKE '%F%') AND (NOT ph_qual LIKE '%X%') AND (NOT ph_qual LIKE '%U%') AND (NOT ph_qual
LIKE '%CC%') AND (NOT ph_qual='CAC') AND (NOT ph_qual='CBC') AND PROX > 6.4 AND mp_flg = '0' AND (b_m_opt is
null OR (b_m_opt - J_M) >= 4.048) AND (vr_m_opt is null OR (vr_m_opt - J_M) >= 2.63) AND (b_m_opt is null OR
vr_m_opt is null OR (b_m_opt - vr_m_opt) >= 1.3)
```

• [AIIWISE](#) :

```
(GLAT > 15 OR GLAT < -15) AND (W1MPRO - W2MPRO) >= 0.168 AND (W1MPRO - W2MPRO) < 2.5 AND ( W3SNR < 5 OR (NOT W3SAT =
0) OR ( (W1MPRO - W2MPRO) > (0.96*(W2MPRO - W3MPRO)-0.96) ) ) AND (cc_flags NOT LIKE '_D_' AND cc_flags NOT
LIKE '_D_' AND cc_flags NOT LIKE '_O_' AND cc_flags NOT LIKE '_O_' AND cc_flags NOT LIKE '_P_' AND cc_flags
NOT LIKE '_P_' AND cc_flags NOT LIKE '_H_' AND cc_flags NOT LIKE '_H_' ) AND (EXT_FLG = '0' OR EXT_FLG = '1')
AND W1SNR > 5 AND W2SNR > 5 AND W1RCHI2 < 5 AND W2RCHI2 < 5 AND W1MPRO > 2 AND W2MPRO > 2 AND W1SAT < 0.002 AND
W2SAT < 0.002 AND (PH_QUAL LIKE 'AA%' OR PH_QUAL LIKE 'AB%' OR PH_QUAL LIKE 'BA%' OR PH_QUAL LIKE 'BB%') AND (
tmass_key is null OR (R_2MASS >= 0.3 AND (j_m_2MASS - h_m_2MASS) >= 0.506 AND (j_m_2MASS - h_m_2MASS) < 2 AND (
h_m_2MASS - k_m_2MASS) >= 0.269 AND (h_m_2MASS - k_m_2MASS) < 1.6 AND (k_m_2MASS - w1mpro) >= 0.153 AND (
k_m_2MASS - w1mpro) < 2))
```

TABLE 6  
ALL-SKY INPUT SAMPLE OF NEARBY, POTENTIAL  $> M5$  OBJECTS.

Designation	<a href="#">2MASS</a>			Designation	<a href="#">AIIWISE</a>		$\mu_\alpha$ (mas yr <sup>-1</sup> )	$\mu_\delta$ (mas yr <sup>-1</sup> )
	<i>J</i>	<i>H</i>	<i>K<sub>S</sub></i>		<i>W1</i>	<i>W2</i>		
00000027-1534494	10.47 ± 0.02	9.90 ± 0.02	9.63 ± 0.02	000000.46-153448.4	9.40 ± 0.02	9.22 ± 0.02	240.5 ± 9.3	87.4 ± 7.4
00000058-2621542	12.83 ± 0.02	12.27 ± 0.02	11.98 ± 0.02	000000.60-262154.9	11.78 ± 0.02	11.59 ± 0.02	27.2 ± 5.2	-63.1 ± 6.2
00000160-7721530	15.66 ± 0.08	15.09 ± 0.09	14.76 ± 0.13	000002.10-772152.6	14.33 ± 0.03	14.06 ± 0.04	151.6 ± 3.8	32.9 ± 10.0
00000296+2541349	13.34 ± 0.02	12.82 ± 0.02	12.51 ± 0.03	000002.98+254134.4	12.29 ± 0.02	12.09 ± 0.02	29.0 ± 5.2	-40.4 ± 6.1
00000497+3740328	15.66 ± 0.05	15.15 ± 0.08	14.82 ± 0.10	000004.96+374033.4	14.57 ± 0.03	14.32 ± 0.05	-16.0 ± 6.7	56.3 ± 9.6
00000540-5418547	14.23 ± 0.03	13.70 ± 0.04	13.39 ± 0.04	000005.29-541855.4	13.20 ± 0.02	13.03 ± 0.03	-85.2 ± 3.7	-64.8 ± 8.5

This table is available in its entirety in the online journal. The complete table has 98 970 rows.

## APPENDIX B: MARGINALLY RED CANDIDATES

We present here the *Low-Priority BASS* ([LP-BASS](#)) sample, consisting of all candidates which were rejected from the [BASS](#) sample because they were less than  $1\sigma$  redder than the field in the  $M_{W1}$  versus  $J-K_S$  and  $M_{W1}$  versus  $H-W2$  CMD diagrams as indicated by the statistical distance of their most probable [BANYAN II](#) membership. However, we still only include candidates which are redder than the field sequence. Using the same method as described in the Paper, we estimate contamination fractions of  $\sim 26\%$  and  $\sim 80\%$  in the high and modest-probability [LP-BASS](#) samples. We thus discourage the use of this for statistical studies or time-consuming follow-ups. However, since the spread in the NIR colors of young objects in the two CMD mentioned above are large, we expect that a fraction of young objects will be rejected by our conservative filter which requires candidates to be  $> 1\sigma$  redder than the field. It is thus likely that this sample will contain a considerable fraction of true members of YMGs. Candidate members in the [LP-BASS](#) are also being following spectroscopically to identify signs of youth, albeit with a lower

priority. Results will be presented in subsequent papers.

In [Table 7](#), we show all measurements in the literature which are useful in constraining the membership of the [LP-BASS](#) candidate members. We use these measurements to refine results from [BANYAN II](#), and report the final probability and most probable YMG for all [LP-BASS](#) objects in [Table 8](#).

We note that [2MASS J00455663+3347109](#) ([G 132–25](#)) had three distinct trigonometric distance measurements in the literature with one being very discrepant : [Reid & Cruz \(2002\)](#) report  $68.0 \pm 18.5$  pc from the [Yale catalog](#) ([van Altena et al. 1995](#)), [Khovritchev et al. \(2013\)](#) measure  $20.1 \pm 2.1$  pc, and [Dittmann et al. \(2014\)](#) measure  $17.4 \pm 1.3$  pc. We thus consulted the [Yale catalog](#) directly to verify the measurement. Sky coordinates are reported as of 1900 in the catalog; we thus used the [precess](#) IDL routine from the [IDL Astronomy Users Library](#)<sup>7</sup> to precess the coordinates of [G 132–25](#) back to this epoch. We find RA=00h40m32.625s, DEC=33°14'21".78. The closest entry in the [Yale catalog](#) is that of [LP 294–2](#), at a distance of 4'. Since [LP 294–2](#) has a distinct [2MASS](#)

<sup>7</sup> Available at <http://idlastro.gsfc.nasa.gov/>

counterpart (2MASS J00461297+3350108), we conclude the most probable explanation is that the trigonometric distance of LP 294-2 has been misattributed to G 132-25 in Reid &

Cruz (2002). We thus rejected this measurement and combined the two others to obtain  $18.1 \pm 1.3$  pc in Table 7.

TABLE 7  
LP-BASS CANDIDATES WITH ADDITIONAL INFORMATION IN THE LITERATURE.

2MASS Designation	Measured SpT <sup>a</sup>	Signs of Youth <sup>b</sup>	RV (km s <sup>-1</sup> )	Trig. Dist. (pc)	Multipli- city <sup>c</sup>	Known Membership	Updated Membership	Updated Prob. (%)
00165057-7122387	...	...	$-3.4 \pm 3.0^{54}$	...	...	...	THA	36.6
00192753-3620153	M5.5 <sup>12</sup>	...	...	...	...	...	THA	11.5
00281434-3227556	M5 <sup>85</sup>	...	...	...	...	...	BPMG	30.4
00303013-1450333	L7 <sup>14,47</sup>	...	...	$26.7 \pm 3.2^{110}$	...	...	ARG	24.1
00425349-6117384	M4.2 <sup>53</sup>	...	$6.9 \pm 1.0^{53}$	...	...	THA <sup>53</sup>	THA	99.9
00455663+3347109	M4.5+M5.5 <sup>55</sup>	...	...	$18.1 \pm 1.3^{47,23}$	AB <sup>55</sup>	...	ARG	89.7
00551459+4511019	...	...	...	$35.8 \pm 3.3^{23}$	...	...	ABDMG	19.3
00584253-0651239	L0 <sup>14,48,27</sup>	...	...	$29.6 \pm 3.5^{71}$	...	...	BPMG	88.6
01000219-6156270	M6 <sup>12</sup>	...	...	...	...	...	THA	99.1
01044008+1129485	...	N <sup>92</sup>	...	...	...	ABDMG <sup>92</sup>	BPMG	76.5
01234181-3833496	M4.5 <sup>78</sup>	...	$18.4 \pm 6.3^{101}$	...	...	...	BPMG	0.6
01253196-6646023	M4.2 <sup>53</sup>	...	$7.1 \pm 5.1^{53}$	...	...	THA <sup>53</sup>	THA	99.7
01275875-6032243	M4.2 <sup>90,53</sup>	N	$9.1 \pm 2.5^{53}$	...	...	THA <sup>90,53</sup>	THA	> 99.9
01283025-4921094	M4.1 <sup>53</sup>	...	$6.5 \pm 5.7^{53}$	...	...	THA <sup>53</sup>	THA	99.3
01375879-5645447	M3.9 <sup>53</sup>	...	$8.5 \pm 0.6^{53}$	...	...	THA <sup>53</sup>	THA	99.9
01534955+4427284	...	...	...	$20.2 \pm 1.2^{23}$	...	...	ARG	98.5
02001992-6614017	M4.3 <sup>90,53</sup>	N	$11.8 \pm 1.1^{53}$	...	...	THA <sup>90,53</sup>	THA	> 99.9
02025788-3136262	M4.0 <sup>90</sup>	N	...	...	...	FIELD <sup>90</sup>	COL	40.7
02030658-5545420	M4.5 <sup>90</sup>	N	...	...	...	ABDMG <sup>90</sup>	THA	99.9
02033222+0648588	...	...	...	...	C <sup>113</sup>	ABDMG <sup>92</sup>	BPMG	64.5
02123372-6049185	M6.5 <sup>34</sup>	...	$13.1 \pm 0.2^{34}$	...	...	...	THA	94.8
02190228+2352550	M3.6 <sup>99</sup>	X <sup>99</sup>	$15.7 \pm 0.7^{100}$	$20.6 \pm 0.8^{23}$	...	...	ARG	72.2
02294569-5541496	M4.8 <sup>53</sup>	L <sup>53</sup>	$11.5 \pm 1.0^{53}$	...	...	THA <sup>53</sup>	THA	> 99.9
02341866-5128462	M4.3 <sup>53</sup>	...	$10.9 \pm 0.9^{53}$	...	...	THA <sup>53</sup>	THA	> 99.9
02351494+0247534	...	...	...	$17.8 \pm 1.0^{23}$	...	...	BPMG	77.6
02383255-7528065	M4.1 <sup>53</sup>	...	$12.3 \pm 0.6^{53}$	...	...	THA <sup>53</sup>	THA	98.9
02412721-3049149	M4.7 <sup>90,53</sup>	ON <sup>90</sup>	$18.2 \pm 1.1^{53}$	...	...	THA <sup>90,53</sup>	BPMG	88.3
02420204-5359147	M4.6 <sup>90,53</sup>	N	$11.5 \pm 2.3^{53}$	...	...	THA <sup>90,53</sup>	THA	> 99.9
02591904-5122341	M5.4 <sup>53</sup>	L <sup>53</sup>	$11.0 \pm 2.3^{53}$	...	...	THA <sup>53</sup>	THA	> 99.9
03090022-4924513	M4.5 <sup>84</sup>	...	...	...	...	...	ARG	18.8
03104941-3616471	M4.3 <sup>90,53</sup>	N	$13.8 \pm 1.6^{53}$	...	...	THA <sup>90,53</sup>	THA	> 99.9
03341065-2130343	M6 <sup>14</sup>	...	$19.0 \pm 0.8^{34}$	...	...	IC 2391 <sup>734</sup>	BPMG	22.9
03370359-1758079	L4.5 <sup>1</sup>	...	...	...	...	...	ARG	11.6
03561624-3915219	M5.0 <sup>90,53</sup>	N	$16.7 \pm 0.7^{53}$	...	...	THA <sup>90,53</sup>	THA	99.9
04032484+0824508	...	X <sup>92</sup>	...	...	...	ABDMG <sup>92</sup>	BPMG	96.7
04054799-1515399	M8 <sup>45</sup>	...	...	...	...	...	THA	70.1
04111790-0556489	M9 <sup>111</sup>	...	$20.1 \pm 5.0^{111}$	...	...	...	COL	20.6
04133609-4413325	M3.9 <sup>90,53</sup>	N	$16.4 \pm 1.4^{53}$	...	...	THA <sup>90,53</sup>	THA	99.6
04231498-1533245	...	...	...	$22.4 \pm 1.0^{23}$	AB <sup>26</sup>	...	BPMG	93.3
04390494-0959012	M6 <sup>13</sup>	...	...	...	...	...	ABDMG	15.4
04475779-5035200	M4.0 <sup>53</sup>	...	$18.6 \pm 0.9^{53}$	...	...	THA <sup>53</sup>	COL	72.0
05195412-0723359	M4+M4.5 <sup>85,43</sup>	X <sup>85</sup>	...	...	AB <sup>43</sup>	...	COL	89.7
06142994-6318559	...	...	...	...	Ab <sup>73</sup>	...	ARG	89.0
06313103-8811365	M5 <sup>102</sup>	...	...	...	...	...	ARG	28.1
07135309-6545115	...	...	...	...	AB <sup>26</sup>	...	CAR	91.5
07140394+3702459	M8 <sup>94,82,27</sup>	...	...	$12.5 \pm 0.7^{23}$	...	...	ARG	74.9
07355465+3333459	M4.5 <sup>78</sup>	...	...	$32.4 \pm 2.5^{23}$	...	...	ABDMG	26.2
10023100-2814280	M4+M6 <sup>80</sup>	...	...	...	AB <sup>43</sup>	...	CAR	93.7
10134260-2759586	M5 <sup>38</sup>	...	...	...	...	TWA <sup>38</sup>	CAR	43.5
10451718-2607249	M8 <sup>38,82,27</sup>	...	...	...	...	...	ABDMG	18.2
15031325-2840134	M5 <sup>78</sup>	...	...	...	...	...	ABDMG	4.3
20042845-3356105	M4.5 <sup>85</sup>	X <sup>85</sup>	...	...	...	...	BPMG	93.8
21144103-4339531	...	...	$2.7 \pm 0.3^{34}$	...	...	CAS <sup>34</sup>	ABDMG	74.5
21272613-4215183	M8 <sup>82</sup>	...	$-7.6 \pm 0.3^{34}$	$34.6 \pm 7.5^{108}$	...	Pleiades <sup>34</sup>	BPMG	82.5
21380269-5744583	M3.7 <sup>53</sup>	...	$-0.5 \pm 1.3^{53}$	...	...	THA <sup>53</sup>	THA	98.7
21414678-2704542	M4.5 <sup>78</sup>	...	...	...	...	...	ABDMG	45.7
22021125-1109461	M6.5 <sup>77</sup>	...	$-9.4 \pm 1.0^{40}$	...	...	...	ABDMG	84.9
22043859-1832204	M4.5 <sup>5</sup>	...	$-7.2 \pm 3.8^{52}$	...	...	...	BPMG	26.3
22294830-4858285	M4.5 <sup>80</sup>	...	...	...	...	...	BPMG	21.1
22302626-0142063	M4 <sup>5</sup>	...	...	...	...	...	ABDMG	14.6
22541103+1606546	M4 <sup>42</sup>	...	...	$30.2 \pm 1.3^{23}$	...	...	ARG	68.8
23261182+1700082	M4.5+M6 <sup>43</sup>	...	...	...	AB <sup>43</sup>	...	BPMG	66.8



TABLE 7 — *Continued*

<i>2MASS</i> Designation	Measured SpT <sup>a</sup>	Signs of Youth <sup>b</sup>	RV (km s <sup>-1</sup> )	Trig. Dist. (pc)	Multipli- city <sup>c</sup>	Known Membership	Updated Membership	Updated Prob. (%)
23301129-0237227	M6 <sup>81</sup>	...	...	...	...	...	BPMG	42.8
23310161-0406193	M8+L3 <sup>9</sup>	...	-12.86 ± 0.09 <sup>9,115</sup>	26.1 ± 0.4 <sup>109</sup>	AB <sup>9</sup>	...	ABDMG	0.5
23524562-5229593	M4.6 <sup>53</sup>	L <sup>53</sup>	3.1 ± 0.7 <sup>53</sup>	...	...	THA <sup>53</sup>	THA	99.9

<sup>a</sup> The  $\beta$  and  $\gamma$  symbols stand for low-gravity and very low-gravity,  $p$  stands for peculiar, and a semi-colon indicates an uncertain spectral type.

<sup>b</sup> A capital letter means the object displays the associated sign of youth. O: lower-than normal equivalent width of atomic species in the optical spectrum, I: same but in the NIR spectrum, T: a triangular-shaped  $H$ -band continuum, V: high rotational velocity, X: X-ray emission, R: redder-than-normal colors for given spectral type, U: over luminous, H:  $H\alpha$  emission, L: Li absorption, A: signs of accretion, M: signs of low gravity from atmospheric models fitting, N: bright NUV emission and C: Companion to a young star. A question mark following a flag indicates that the result is uncertain.

<sup>c</sup> AB: Unresolved binary, B or C: Resolved companion.

References to this table are identical to those of Table 3.

TABLE 8  
THE COMPLETE *LP-BASS* CATALOG.

<i>2MASS</i> Designation	Spectral Type <sup>a</sup>	Probable Membership	Bayesian Prob. (%)	Contamination Prob. (%)	Estimated Mass Range ( $M_{\text{Jup}}$ )	Statistical Distance (pc)	Statistical RV (km s <sup>-1</sup> )
Candidates with a High Probability							
00081980-2559449	(M5.8)	ABDMG	60.1	5.3	87.1 <sup>+8.2</sup> <sub>-7.8</sub>	36.2 <sup>+2.4</sup> <sub>-2.0</sub>	10.0 ± 2.0
00091768+0603461	(M5.2)	ABDMG	36.6	2.4	156.3 <sup>+14.4</sup> <sub>-12.8</sub>	25.3 ± 1.6	-2.0 ± 2.0
00165057-7122387	(M5.7)	THA	36.6	< 0.1	57.7 <sup>+8.1</sup> <sub>-6.3</sub>	47.4 ± 3.2	-3.4 ± 3.0
00165242-7640540	(M5.3)	THA	31.8	< 0.1	85.0 <sup>+11.1</sup> <sub>-8.9</sub>	45.4 <sup>+3.2</sup> <sub>-2.8</sub>	6.4 ± 2.4
00200551-5359372	(M6.2)	THA	98.9	< 0.1	36.2 <sup>+9.3</sup> <sub>-6.7</sub>	39.8 <sup>+2.4</sup> <sub>-2.0</sub>	5.3 ± 2.4
00303013-1450333	L7	ARG	24.1	2.6	10.4 <sup>+0.6</sup> <sub>-0.4</sub>	26.7 ± 3.2	4.3 ± 2.0
00381489-6403529	(M8.6)	THA	99.7	< 0.1	15.3 <sup>+0.7</sup> <sub>-0.4</sub>	44.2 ± 2.4	7.5 ± 2.4
00425349-6117384	M4.2	THA	99.9	< 0.1	123.0 <sup>+13.6</sup> <sub>-13.1</sub>	42.6 ± 2.4	6.9 ± 1.0
00455663+3347109	M4.5+M5.5	ARG	89.7	0.1	86.4 <sup>+8.4</sup> <sub>-7.7</sub>	18.1 ± 1.3	4.3 ± 1.4
00474453+4159428	(M3.7)	BPMG	49.0	14.4	169.0 <sup>+10.5</sup> <sub>-11.0</sub>	30.5 ± 2.8	-3.2 ± 2.2
Candidates with a Modest Probability							
00085614-2813211	(L8.9)	BPMG	21.5	21.8	6.1 ± 0.1	16.1 ± 1.2	5.8 ± 1.5
00102936-0746487	(M6.2)	ABDMG	18.2	19.9	74.3 <sup>+7.0</sup> <sub>-6.6</sub>	43.8 <sup>+3.2</sup> <sub>-2.8</sub>	3.3 ± 2.1
00192753-3620153	M5.5	THA	11.5	43.0	60.3 <sup>+8.6</sup> <sub>-6.8</sub>	37.8 <sup>+2.0</sup> <sub>-2.4</sub>	0.9 ± 2.2
00193193-0554404	(M5.0)	BPMG	30.8	44.2	89.9 <sup>+6.4</sup> <sub>-6.1</sub>	33.8 <sup>+3.6</sup> <sub>-3.2</sub>	3.2 ± 1.7
00281434-3227556	M5	BPMG	30.4	45.7	168.7 <sup>+10.6</sup> <sub>-11.1</sub>	32.1 <sup>+2.8</sup> <sub>-3.2</sub>	8.1 ± 1.5
00324451+2744454	(M5.0)	BPMG	17.4	36.0	93.9 ± 5.6	35.8 ± 3.2	-3.6 ± 2.0
00465095+3822416	(M5.5)	ARG	15.8	28.2	77.3 <sup>+7.9</sup> <sub>-8.2</sub>	33.8 <sup>+3.2</sup> <sub>-3.6</sub>	2.3 ± 1.7
00473149-1424425	(M4.8)	BPMG	54.3	34.2	100.0 <sup>+5.7</sup> <sub>-6.3</sub>	30.9 ± 2.8	6.9 ± 1.5
00584590+2430511	(M5.8)	BPMG	24.8	27.3	46.8 ± 2.6	31.3 ± 2.8	2.2 ± 2.1
01012488-2412472	(M6.0)	BPMG	12.1	30.2	41.5 <sup>+2.8</sup> <sub>-2.5</sub>	23.3 ± 2.0	9.3 ± 1.5

<sup>a</sup> Spectral types in parentheses were estimated from *2MASS-AllWISE* colors (see Section 4.1).

<sup>b</sup> The binary hypothesis is more probable than the single hypothesis (see Section 3).

This table is available in its entirety in the online journal. The complete table has 249 rows.

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